March 20, 2013

Mr. Nile Ostenso
Wisconsin Department of Natural Resources
101 S. Webster Ave.
Madison, WI 54701

Dear Mr. Ostenso:

WPDES Permit No. WI-0000965-09-0
Pulliam Generating Station
<u>Comments on the Proposed WPDES Permit for the Pulliam Generating Station</u>

References: 1) Updated Thermal Effluent Limitations for Green Bay MSD (WI-0020991) and Wisconsin Public Service – Pulliam (WI-0000965), dated November 21, 2011
2) Implementation Guidance for Wisconsin's Thermal Water Quality Standards
3) Technical Support Document for Wisconsin's Thermal Water Quality Rules, 10/22/2007 (Draft)

Wisconsin Public Service Corporation (WPSC) is providing the following comments on the proposed WPDES permit for the J.P. Pulliam Generating Station (Pulliam). The proposed permit was published for public review and comment on February 20, 2013. New conditions proposed in the permit include temperature limitations derived as a result of the October 2010 revisions to NR 102 and NR 106. WPSC has reviewed the proposed permit and has the following comments.

<u>Effluent Temperature Limitations in Section 4.2.1</u>

The Pulliam plant is located at the confluence of what are classified as two separate water bodies: the lower Fox River (from Lake Winnebago to the mouth of the Fox River) is classified as a large, warm water sport or forage fish community, while Southern Green Bay (from the Brown County Line to the mouth of the Fox River) is classified as a Great Lakes cold-water community. The location of the facility at the mouth of the Fox River and Green Bay presents a unique situation when evaluating the discharge from the facility for compliance with water quality based effluent limitations for temperature as there are two separate and distinct water bodies with different water quality criteria. The discharge from the Pulliam plant is near the mouth of the river and essentially discharges into Southern Green Bay in close proximity to where the Fox River flows into Green Bay.

The effluent temperatures included in Permit Section 4.2.1 were calculated using the procedure found in NR 106.55(7). The procedure assumes a default configuration where a facility is a shoreline discharger to a Great Lake water body. A flaw in this technical approach is that the methodology does not contain a mechanism to address situations where there is a confluence and transition between two water use communities. The regulations assume that water flowing from the Fox River into Southern Green Bay is instantaneously at different temperatures at the mouth of the river, which is truly not the case. The methodology for calculating effluent limitations has to acknowledge the natural mixing/transition zone between these two water bodies when calculating thermal effluent limitations.

A fundamental issue with the water quality criteria for the lower Fox River compared to Southern Green Bay is that the default ambient temperature for the Fox River is equal to or greater than the sub-lethal water quality criteria for Southern Green Bay during the months of June through August. A simple comparison of the default ambient temperatures of the Fox River versus the sub-lethal water quality criteria for Southern Green Bay would lead one to believe that the Fox River itself is causing adverse impacts. As found in Reference 1;

> In theory, the ambient river temperatures would cause exceedances of the criteria in the bay during those months even if no discharges were present, but it is still assumed (that) some cooling and mixing occurs out in the bay, and that justified the NR 102 criteria for southern Green Bay in the first place.

If the "assumption" when the criteria for Southern Green Bay was developed is that there is a natural mixing zone at the confluence of the Fox River and Green Bay, then that mixing zone must be taken into account when setting the thermal effluent limits for the Pulliam plant discharge. NR 106.55(10) provides the Department with the discretion to calculate limitations based upon a site specific mixing zone. While the calculations conducted in reference 1 do account for some influence of the Fox River on the temperature limitations (i.e., a slightly larger mixing zone due to the width of the Fox River), the calculations do not account for the additional length of the natural mixing/transition zone between the Fox River and Green Bay. By only increasing one dimension of the mixing zone in the calculations, the Department did not use its full discretion to identify the area already affected by the thermal discharge from the Fox River itself.

A consequence of the effluent limitation calculation procedure is that excessively restrictive water quality based effluent limitations (WQBELs) are derived. The proposed weekly average effluent limitations in the proposed permit for the months of June through August are less than or equal to the *default ambient* temperatures for the lower Fox River in NR 102. As stated in Reference 1, if the justification for establishment of the criteria for Southern Green Bay is an assumption that ambient

conditions in the Fox River will result in attaining the water quality criteria, then logically calculated limitations that are less than default ambient temperatures are not realistic. Since the discharge from the facility is not in the "default" configuration of a shoreline discharge and there is another discharger (the Fox River itself), effluent limitations for the facility must be evaluated acknowledging the mixing/transition zone for the Fox River when establishing effluent limitations for the facility. Effluent limitations should be calculated and evaluated based upon the size of the natural mixing/transition zone from the Fox River. The Department should first consider the natural transition zone created by the Fox River into Southern Green Bay and then determine WQBELs for temperature based on the size of that mixing zone[1].

Temperature Monitoring and Reporting Requirements

The temperature monitoring and reporting requirements in Permit Sections 4.2.1.7.5 and 4.2.1.7.6 are inconsistent with NR 106 and Department guidance. The methodology to be used to determine compliance with weekly effluent limitations for temperature during transitions between calendar months is described in these permit sections. These permit conditions stipulate that when four days or more of a calendar week fall within a certain calendar month, the weekly effluent temperature limitation that is applicable shall be based upon the associated month with four or more days in the calendar week. This approach contradicts both the current regulations and Department guidance.

As part of the rule development, thermal limits were calculated over *each month* of the year because ambient temperatures and criteria (the allowable increase above ambient) vary from month to month. It is important to recognize that the Department chose not to establish daily or weekly water quality criteria to address changes in ambient temperatures. Instead, the Department chose to establish in the regulations a monthly criteria based on monthly average water temperatures (reference 3).

When calculating effluent limitations using the procedure in NR 106, the rule indicates that the effluent flow rate to be used to calculate limitations is the seven day rolling average effluent flow - the arithmetic mean of the effluent flow from a given day and the six days preceding it during that month (NR 106.52(8)). As found in reference 2, "no weekly average flows would be available for the 1st through the 6th day of the month, but those results would be used to calculate the weekly average on the 7th and afterwards." Therefore, the regulation excludes the flow data from the beginning of a calendar month for a determination of a WQBEL.

1 – WPS requested alternate effluent limitations for temperature based upon a site specific mixing zone analysis in the "Compliance Evaluation of the Thermal Discharge from the J.P. Pulliam Generating Station" report dated December 2010 that was previously submitted to the Department on 12/22/2010. A copy of this report is attached.

The regulations also define weekly average effluent temperature as the arithmetic mean of the results from a calendar week, meaning Sunday through Saturday (NR 106.52(10)). In reference 2, and in the water quality based effluent limitation spreadsheet developed by the Department, weekly average temperatures are only calculated for a week within a month when the whole calendar week is in that month. As found in Reference 2:

> …the weekly average temperatures are only calculated for a week within a month when the whole calendar week is in that month. In the example above, the results from September 1st through the 4th are not used to calculate weekly averages, nor are the results from September 26th through the 30th. Those results are still used to determine the maximum value for the month, though.

As effluent limitations are based in part on effluent flow rates from a facility and the regulation specifically identifies that the average effluent flow is based upon daily flow within a calendar month, then temperature data used for determining compliance with a weekly effluent limitation must also be from the same calendar month. Based on the language of the rule and the Department's guidance, it is apparent that daily temperature data is not to be used to calculate a weekly average effluent temperature unless all temperature data for a calendar week is within the same calendar month. The proposed methodologies for determining compliance with weekly average temperature limitations in Permit Sections 4.2.1.7.5 and 4.2.1.7.6 contradict the regulation and Department guidance and should be removed from the permit.

Finally, the Wisconsin Legislature recently adopted Wis. Stat. § 227.10(2m), which provides:

> No agency may implement or enforce any standard, requirement, or threshold, including as a term or condition of any license issued by the agency, unless that standard, requirement, or threshold is explicitly required or explicitly permitted by statute or by a rule that has been promulgated in accordance with this subchapter.

Pursuant to this statute, WDNR is prohibited from imposing effluent temperature requirements in the draft permit for these partial calendar weeks unless it can point to a statute or administrative rule that explicitly requires or permits the limit. Because WDNR can point to no such statute or rule, the effluent temperature permit condition limitation at issue cannot be included in the permit as part of the methodology for calculating the effluent temperature.

Potential Revision or Removal of Temperature Limitations

Permit Section 4.2.1.8 clarifies that WPSC has the option to request a revision to the limitations proposed pursuant to the procedures in NR 106, subchapter V or VI. The draft permit states that:

> If these various approaches are unsuccessful or not completed prior to June 30, 2018, the thermal limits in the permit table for Outfall 001, Section 4.2.1, become effective on June 30, 2018. Success includes the completion of a permit modification by the June 30, 2018 effective date.

A significant assumption in this proposed language is WDNR's timely processing of WPSC's permit modification request. Should workload factors or other issues prevent the Department from taking timely actions to modify the permit, there is the potential that the effluent limitations will take effect prior to the permit being modified. If the limits take effect, the facility may be restricted from operating during certain months due to the overly restrictive WQBELs for temperature that are in the draft permit.

As stated above, the limits proposed for the months of June through August are less than or equal to the default ambient temperatures for the lower Fox River in NR 102. The permit must clarify that the effluent limitations for temperature listed will not take effect if;

1) WPSC submits and receives approval of an acceptable demonstration for the removal or modification of the temperature limits, and;
2) A request to modify the permit limitations for temperature are submitted prior to the deadline for submitting a permit modification request as found in Section 5.3 of the permit.

Date for a request to modify the temperature limitations in Section 5.3

In Section 5.3, the date listed for the submittal of a permit modification request of the WPDES permit is September 1, 2017 (9 months prior to permit expiration). As the facility is required to submit an application for permit re-issuance 6-months prior to permit expiration, WPSC suggests harmonizing the dates of the permit modification request and permit re-issuance application to the same date: December 30, 2017. Please note that the current compliance date lists in the permit are keyed off of the effective date of the permit. if for any reason the permit issuance is delayed, then the compliance dates listed in the permit will need to be adjusted accordingly.

Standard Requirement for Ammonia

Standard Requirement 6.2.4, "Ammonia Limit Not Needed – Continue to Optimize Removal of Ammonia" is not needed. This standard requirement has not been in previous WPDES permits for the facility. We believe this was included inadvertently and should be removed from the permit.

A total residual chlorine reporting requirement in Section 6.3.6 is inconsistent with the permit.

Condition 6.3.6 outlines the reporting requirements when dechlorinating effluent. The third bullet point in this condition indicates "Samples showing detectable levels greater than 100 µg/l shall be considered exceedances, and shall be reported as measured." The effluent limitations for chlorine found in Section 4.2.1 correctly shows that the total residual chlorine effluent limitation for the facility is 200 µg/l if chlorine is added for 160 minutes per day or less, and 38 µg/l if chlorine is added for more than 160 minutes per day. The bullet should be revised to remove the phrase "shall be considered exceedances" and should only state that values greater than 100 µg/l shall be reported as measured.

WPSC appreciates the opportunity to comment on the proposed WPDES permit. If you have any questions about the information contained in this submittal, please contact Mr. Mark Metcalf at (920) 433-1833 or by e-mail at MWMetcalf@integrysgroup.com.

Sincerely,

Leonard J. Rentmeester
General Manager - Pulliam

Report on the

Compliance Evaluation of the Thermal Discharge from the J.P. Pulliam Generating Station

for

Wisconsin Public Service
Green Bay, Wisconsin

December 2010

Compliance Evaluation of the Thermal Discharge from the J.P. Pulliam Generating Station

prepared for

Wisconsin Public Service
Green Bay, Wisconsin

December 2010

Project No. 52875

prepared by

Burns & McDonnell Engineering Company, Inc.
Kansas City, Missouri

EXECUTIVE SUMMARY

The J.P. Pulliam Generating Station (PGS) is located in Green Bay, Wisconsin, on the Fox River near the river's confluence with Green Bay. Since January 1, 2008, the PGS has operated four, coal-fueled generating units that use once-through cooling. Water is withdrawn from the Fox River through an intake located in a side channel and discharged through a shoreline outfall. The maximum discharge rate for the operating generating units is 422.8 million gallons per day.

The State of Wisconsin recently finalized new water quality standards and criteria for temperature, which will be applicable to the PGS's next WPDES permit. The new Wisconsin temperature criteria vary by month and water body. The temperature criteria and mixing zone standards considered applicable to the PGS were for southern Green Bay because the discharge is at the intersection of the Fox River and Green Bay and water flow at this location is not unidirectional. Based on the default method for calculating water quality-based effluent limitations for discharges into a Great Lake in NR 106, the discharge from the PGS would have a reasonable potential to exceed the sub-lethal temperature criteria at the edge of the mixing zone in all months, and exceed the acute criteria in May through October. The following plume modeling study was conducted to determine if the PGS has a reasonable potential to exceed the new Wisconsin temperature criteria by comparing the characteristics of the thermal mixing zone generated by the PGS to those specified at NR 102.05(3). The study consisted of bathymetric mapping, thermal plume mapping, and discharge plume modeling.

Bathymetric data for the study area were collected on July 20, 2010, using an integrated depth sounder/global positioning system, and were used to prepare a bathymetric map. This map served as a basis for developing a two-dimensional, finite-element model using the hydrodynamic software AQUASEA. *In situ* measurements of temperature were made on July 21, 2010, to map the thermal discharge plume from the PGS. The thermal plume map was used as a benchmark for calibrating the AQUASEA model. Basic input to the model consisted of bathymetry, river flow, wind speed and direction, and cooling water system discharge rates and temperatures from the PGS. Successful calibration of the model required specifying a river flow that was approximately 86 percent less than the average daily flow estimated by the U.S. Geological Survey.

Discharge plume modeling used month-specific conditions including average wind speed, wind direction, Fox River seven-day average low flows with a recurrence interval of 10 years, Wisconsin default ambient temperature and temperature criteria, and maximum discharge temperatures and rates from the PGS to determine the reasonable potential of the PGS discharge to exceed the temperature criteria based on

complying with the mixing zone area limit of 71.74 acres in NR 106.55(7). Modeling found that the mixing zone areas corresponding to the acute temperature criteria were no greater than 0.6 acres for all months, indicating that the PGS did not have a reasonable potential to exceed the acute temperature criteria. Similarly, the mixing zone areas corresponding to the sub-lethal criteria were no greater than 1.70 acres for November through April, indicating no potential to exceed the sub-lethal criteria existed in these months.

The sub-lethal mixing zone areas for May through October exceeded 71.74 acres. Limitations on the size of the modeled study area prevented delineating the entire mixing zones in these months. The May through October sub-lethal mixing zones, however, do comply with the requirements for limits based on site-specific mixing zone analysis in NR 106.55(10). The request sub-lethal temperature limits for these months are the calculated 99th percentile temperatures of all representative weekly average effluent temperatures for the applicable month.

TABLE OF CONTENTS

Page No.

APPENDIX A - TEMPERATURE MEASUREMENTS OF THE THERMAL PLUME

APPENDIX B - HEAT LOSS PARAMETER CALCULATIONS

LIST OF TABLES

Page No.

LIST OF FIGURES

Page No.

1.0   INTRODUCTION

The J.P. Pulliam Generating Station (PGS) is located in Green Bay, Wisconsin, on the Fox River near the river's confluence with Green Bay. Since January 1, 2008, the PGS has operated four coal-fueled generating units that use once-through cooling. Water is withdrawn from the Fox River through an intake located in a side channel and discharged through a shoreline outfall (Figure 1-1). The maximum discharge rate for the active generating units is 422.8 million gallons per day (MGD). The PGS is currently operated more or less continuously to provide baseload power.

Figure 1-1:   J.P. Pulliam Generating Station
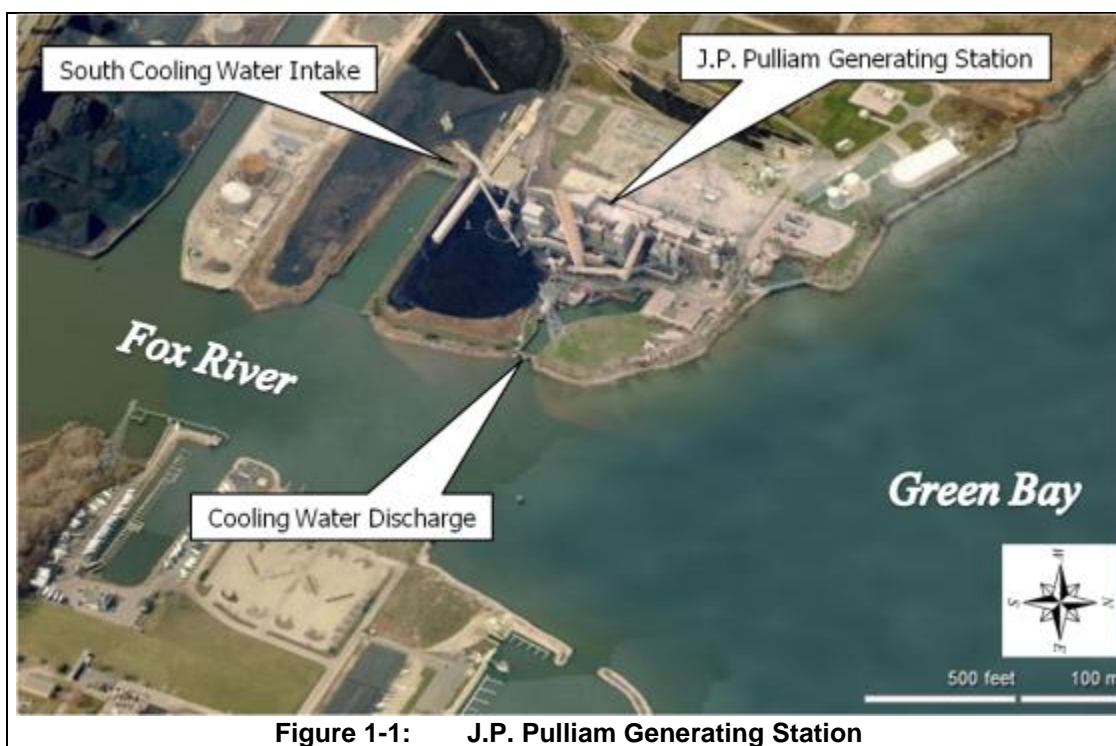
Effluent from the cooling water system is initially discharged into an open channel, then into the Fox River through a split, 1.22-m deep (at typical water elevation) shoreline opening (Figure 1-1). The south opening is 4.191 m wide and the north opening is 3.962 m wide. The two openings are separated by 5.82 m.

On October 1, 2010, the State of Wisconsin finalized new water quality standards and criteria for temperature, which will be applicable to the PGS's next WPDES permit. The new Wisconsin temperature criteria vary by month and water body. The temperature criteria and mixing zone standards considered applicable to the PGS were for southern Green Bay (Table 1-1) because the discharge is at the intersection of the Fox River and Green Bay. Water flow at this location is not unidirectional. For a

Table 1-1:   Temperature criteria for the protection of aquatic life applicable to the Pulliam Generating Station

Month	Default ambient °F	°C	Sub-lethal °F	°C	Acute °F	°C
January	35	1.7	49	9.4	75	23.9
February	35	1.7	52	11.1	75	23.9
March	41	5.0	54	12.2	77	25.0
April	47	8.3	58	14.4	79	26.1
May	56	13.3	64	17.8	81	27.2
June	66	18.9	70	21.1	83	28.3
July	70	21.1	75	23.9	83	28.3
August	70	21.1	75	23.9	83	28.3
September	65	18.3	70	21.1	83	28.3
October	54	12.2	60	15.6	80	26.7
November	39	3.9	49	9.4	76	24.4
December	37	2.8	46	7.8	75	23.9
NR 102, Table 5						

shore discharge into a Great Lake, mixing zones should have a surface area no larger than 3,125,000 feet^2 or 71.74 acres (NR 106.55(7)(b)), and provide a passage around the mixing zone for fish and other mobile aquatic organisms (NR 102.05(3)(b)). In practice, default water quality-based effluent limitations for discharges into a Great Lake are calculated using a heat-loss model (NR 106.55(7)(b)). For temperature, limits are calculated for each month using site-specific inputs where applicable. Based on this approach, the temperature of the discharge from the PGS would have a reasonable potential to exceed the sub-lethal temperature criteria at the edge of the mixing zone in all months, and exceed the acute criteria in May through October (Table 1-2). The regulations, however, allow limitations to be calculated based on site-specific mixing zone analysis (NR 106.55(10)) and upon water quality modeling information, as allowed in NR. 106.55(13). In this case, the limitations must comply with the mixing zone provisions of NR 102.05(3).

The following study was conducted to determine if the PGS has a reasonable potential to exceed the new Wisconsin temperature criteria by comparing the characteristics of the thermal mixing zone generated by the PGS to those specified at NR 102.05(3). The study consisted of bathymetric mapping, thermal plume mapping, and discharge plume modeling. The bathymetric map provided essential input information into the plume model, and the plume mapping served as a basis to calibrate the model.

Table 1-2:   **Reasonable potential to exceed analysis for the Pulliam Generating Station based on NR 106.55**

Month	T_a (°F)	Default WQCs Sub-lethal (°F)	Acute (°F)	Qe (MGD)	e^{-a}	a	Mixing Zone (feet^2)	B	Default Sub-Lethal LIMIT (°F)	Acute LIMIT (°F)	Maximum 7-day average (°F)	Daily maximum (°F)
January	35	49	75	422.80	0.9030	0.1021	3,125,000	0.405	51	79	60	64
February	35	52	75	422.80	0.9030	0.1021	3,125,000	0.405	54	79	56	63
March	41	54	77	422.80	0.9030	0.1021	3,125,000	0.405	55	81	68	70
April	47	58	79	422.80	0.9030	0.1021	3,125,000	0.405	59	82	76	78
May	56	64	81	422.80	0.9030	0.1021	3,125,000	0.405	65	84	91	98
June	66	70	83	422.80	0.8852	0.1220	3,125,000	0.555	71	85	94	96
July	70	75	83	422.80	0.8721	0.1368	3,125,000	0.667	76	85	98	99
August	70	75	83	422.80	0.8721	0.1368	3,125,000	0.667	76	85	101	103
September	65	70	83	422.80	0.8852	0.1220	3,125,000	0.555	71	85	95	96
October	54	60	80	422.80	0.9030	0.1021	3,125,000	0.405	61	83	90	93
November	39	49	76	422.80	0.9030	0.1021	3,125,000	0.405	50	80	77	78
December	37	46	75	422.80	0.9030	0.1021	3,125,000	0.405	47	79	61	65

LIMIT = $[(WQC - T_a) / (e^{-a})] + T_a$ = exceeds LIMIT

Note: The reasonable potential analysis was performed using the design circulating water flow for the operating units and the higher of observed or projected 99th percentile temperatures for the facility.

2.0   BATHYMETRIC MAPPING

Bathymetric data for the study area were collected on July 20, 2010, from 15:57 to 16:52, using a Seafloor Systems Hydrolite integrated depth sounder/global positioning system (GPS). This system consisted of an Ohmex SonarMite echo sounder and a Trimble XT handheld GPS augmented with an

external antenna. The system was attached to a boat that was piloted around the perimeter of the study areas and along numerous transects across the area (Figure 2-1). Latitude/longitude/depth points were measured and recorded at approximately one-second intervals, and 8549 usable data points were collected. During the data collection period, surface water elevation at U.S. Geological Survey (USGS) gaging station 040851385 Fox River at Oil Tank Depot at Green Bay, Wisconsin,[1] ranged from 578.44 to 578.72 feet above mean sea level (Figure 2-2).

The latitude and longitude points for the shoreline, representing zero depth, were obtained from U.S. Census Bureau's Topologically Integrated Geographic Encoding

Figure 2-1:   Sonar path for bathymetric mapping

Figure 2-2:   Fox River Elevation at Green Bay during Bathymetric Mapping

---
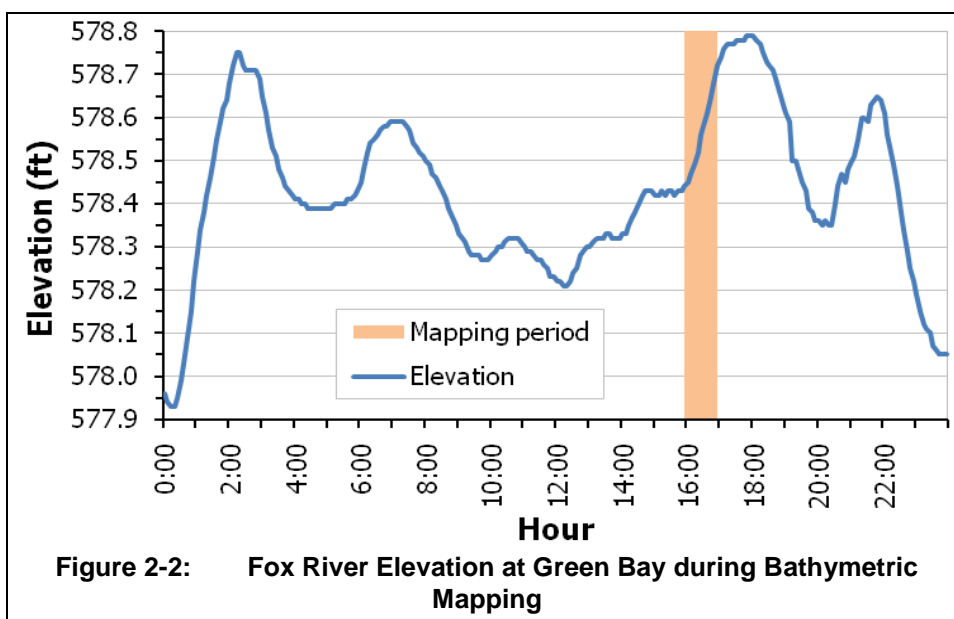
[1]This gaging station is referred to by the National Oceanic and Atmospheric Administration as GBYW3 or 9087079.

and Referencing database and adjusted by hand digitizing where needed to match a background image of the lake. The depth data were extrapolated to a 3- by 3-meter matrix using the software Hypack, which contains a triangulated irregular network algorithm specific for preparing bathymetric maps. The matrix was then imported into the ArcInfo geographic information system (GIS) and the 3-D Analyst sub-system was used to produce the depth contours (Figure 2-3).

Figure 2-3:   Bathymetric map of the mouth of the Fox River
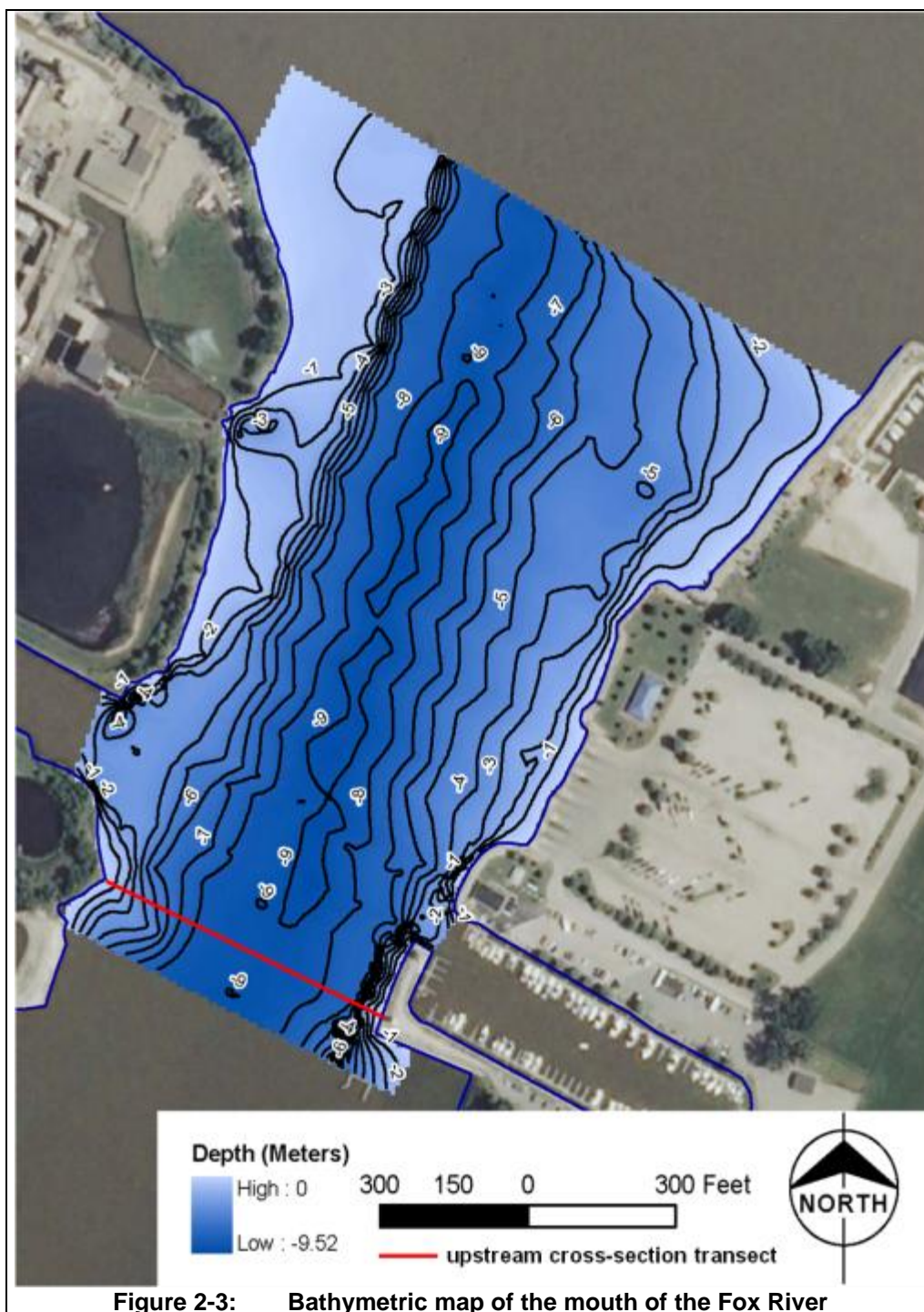
A cross-section of the river along a transect at the upstream end of the study area was analyzed (Figure 2-4). This transect had a length of 200 m, a maximum depth of 9 m, a cross-sectional area of 1236 m^2, and an average depth of 6.18 m. Based on the USGS estimated average flow of 12,600 cfs on July 21, the average velocity through the cross-section would have been 0.29 m/s (0.95 feet per second).

Figure 2-4:   Upstream cross-section of the Fox River
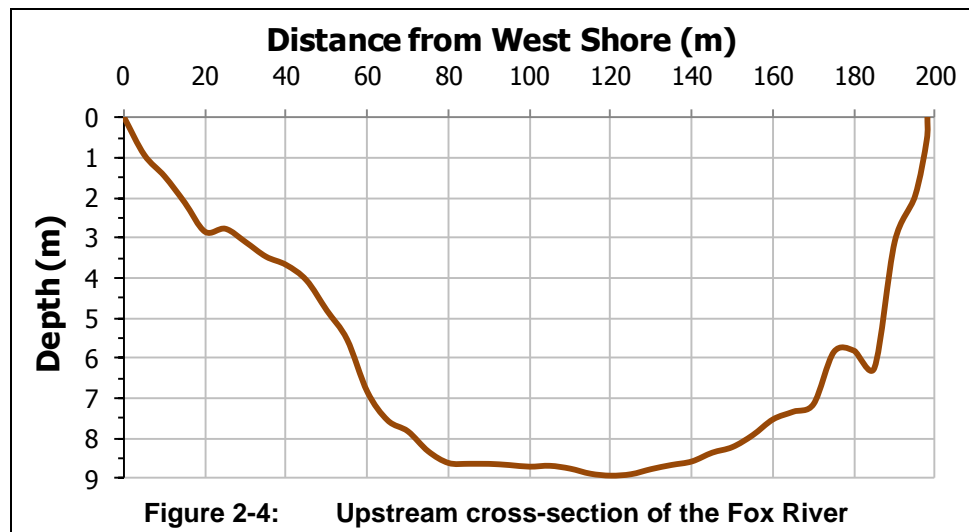
3.0   THERMAL PLUME MAPPING

The thermal discharge plume from the PGS was mapped on July 21, 2010, from 08:45 to 14:30. The cooling system discharge rate was 295.2 MGD and discharge temperature measurements made by the PGS at the outfall at 15-minute intervals ranged from 88.8 to 89.4 ºF and averaged 89.1 ºF. Intake water temperatures ranged from 76.2 to 77.5 ºF and averaged 76.9 ºF. The average change in temperature (ΔT) between the intake and outfall was 12.2 ºF. Generating output ranged from 73.5 to 78.1 percent of capacity and averaged 75.7 percent.

The USGS gaging station Fox River at Oil Tank Depot is a real-time station that can provide data for stage (water surface elevation), velocity, discharge, and temperature at five-minute intervals. The velocity and discharge data, however, were not available for July 17, 05:55, 2010, through July 22, 11:35, 2010, presumably because of instrument malfunction (Figure 3-1). Later in 2010, the USGS issued estimated daily average flows for these days, which for July 21 was 12,600 cfs. Because of the proximity to Green Bay, flow in the Fox River near the mouth is heavily influenced by changes in surface elevation of Green Bay, which results in highly variable flow rates and even negative (upstream) flow direction (Figure 3-1). For May 25 through July 17, 2010, the average daily range in flow was 18,267 cfs. Based on plus or minus one-half of the average daily range, the flow in the Fox River at any given time on July 17, therefore, could be expected to have ranged from 21,734 to 3,466 cfs.
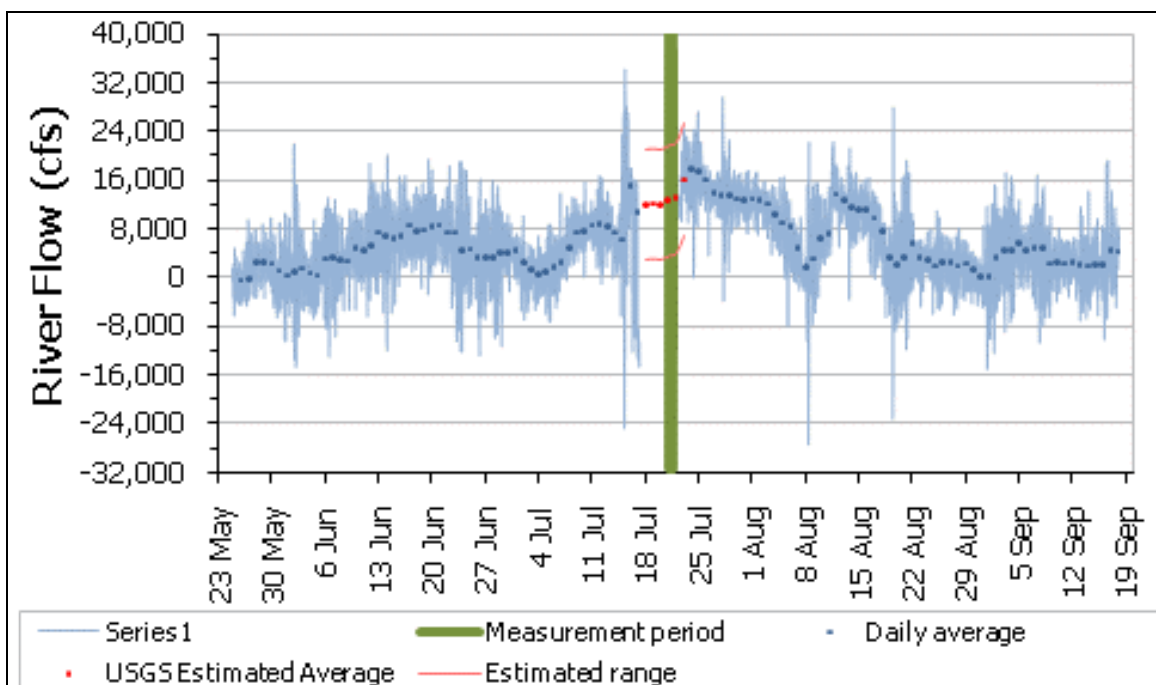
Figure 3-1:   Flow in the Fox River at Green Bay, Wisconsin, May 23 through September 19, 2010

The plume was mapped by making *in-situ* measurements of temperature with the thermistor portion of an Oakton model Con10/pH meter and submersible probe. The thermistor was calibrated to a National Institute of Standards and Technology-traceable mercury thermometer just prior to use. The probe was attached to the end of a 10- to 20-foot telescoping pole. At each measurement point, a 130-pound hydrographic torpedo was lowered by winch to the bottom of the lake. The cable to the torpedo was kept taut to provide a vertical reference line. The probe end of the pole was clipped to the cable and temperature measurements were recorded at 1.64-foot (0.5-meter (m)) intervals as the probe was lowered down the cable.

Temperature measurements were made at points along transects extending from shore. The first sampling point on each transect was within two meters of the shoreline and the last point was where the water temperature had returned to ambient or the far side of the study area was reached. In between, sampling points were concentrated near the shoreline where horizontal changes in temperature were greatest. The most upstream (southern) transect was located outside of the thermal plume (Figure 3-2). The most downstream (northern) transect was located in Green Bay. At all sampling points, depth of temperature measurements exceeded the thickness of the thermal plume. The location of each sampling point was determined using a Trimble GeoXT GPS equipped with an external antenna and a Trimble GeoBeacon for real-time differential correction and sub-meter accuracy. The temperature data collected are provided in Appendix A.

The surface temperature at each measurement point was plotted on an aerial image of the study area. Lines of equal temperature were drawn by hand on the image using linear interpolation between adjacent points and best professional judgment. Similar maps were made for the temperature data collected at depths of 1.0, 2, 3, and 2.0 m. No temperatures above ambient were observed at depths of 4.5 m or greater.

The thermal plume emanated from the discharge point approximately perpendicular to the shoreline and exhibited a characteristic fusiform shape (Figure 3-3). At approximately 300 feet from the discharge point, the plume centerline curved in the downstream direction. The trajectory of the plume centerline out into the bay, however, was not smooth. This irregular path is consistent with flow and velocity in the river that are relatively slow and variable. An intrusion of slightly warmer water was observed along the west shore north of the discharge point (Figure 3-3). This intrusion could have been from naturally warmer water circulating in from a shallow portion of Green Bay. The size of the discharge plume decreased rapidly with increasing depth (Figure 3-4).

Figure 3-2:   Temperature measurement points for mapping the thermal plume at the Pulliam Generating Station

Figure 3-3:   **Map of the Pulliam Generating Station thermal plume at the surface**

Figure 3-4:   Map of the Pulliam Generating Station thermal plume at 1, 2, 3, and 4 meters
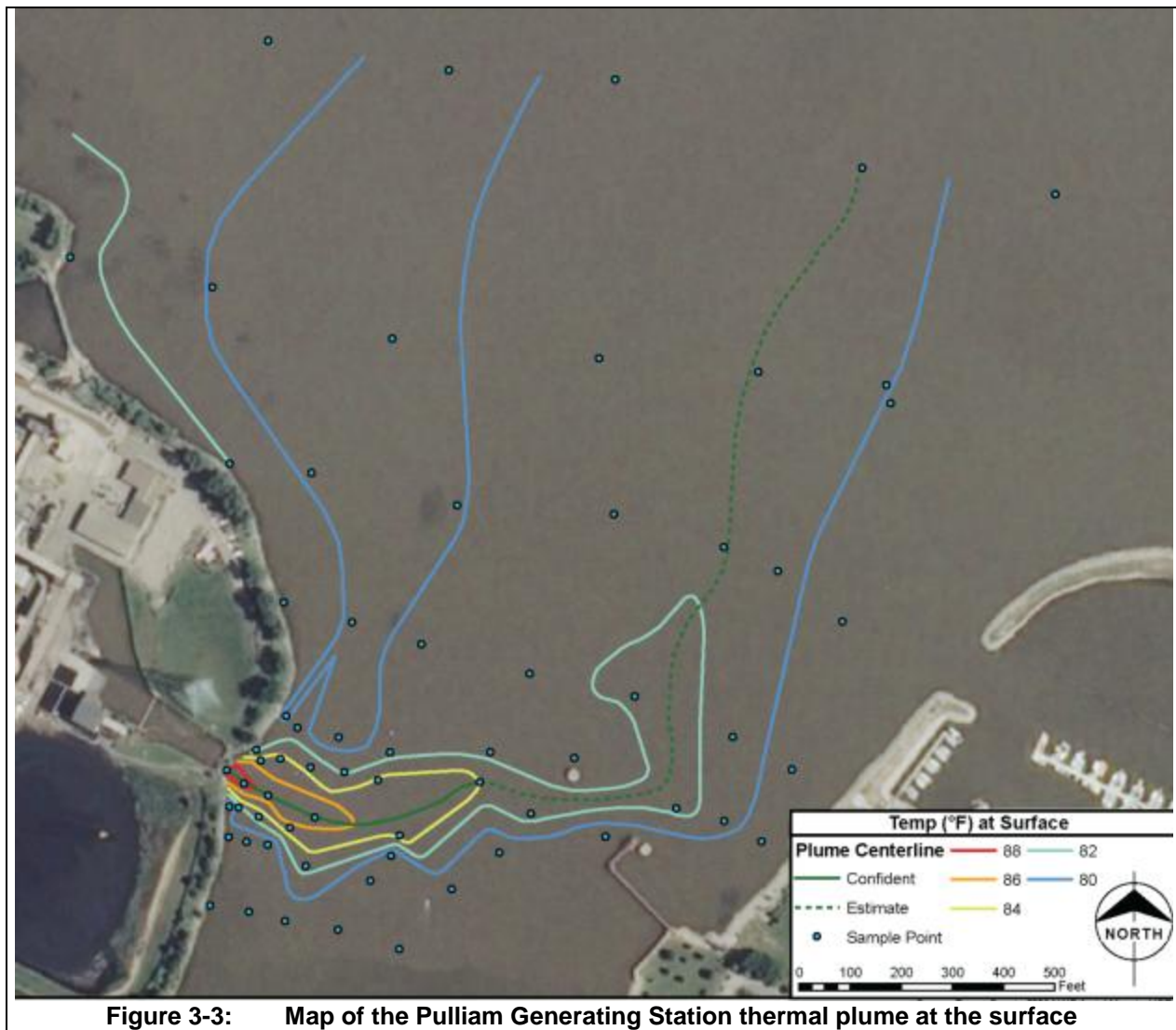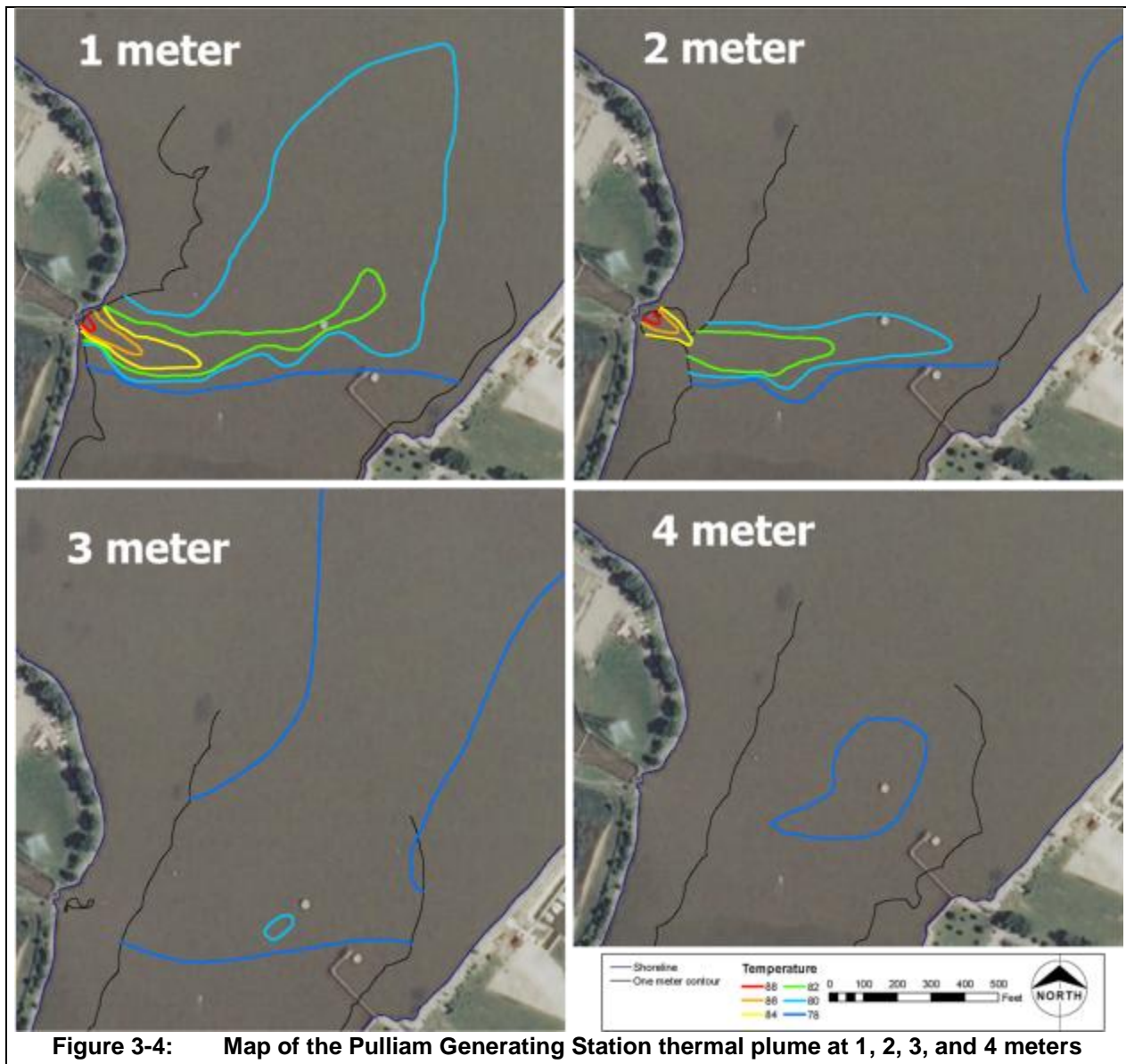
4.0   MODEL DEVELOPMENT

The discharge plume was modeled using AQUASEA (version 7.2). This software package uses a two-dimensional, finite element model to estimate water flow and pollutant transport and dispersion over time. AQUASEA was found to provide a better match to the observed discharge plume than CORMIX. Specifically, CORMIX would not model the discharge plume past the region of active mixing (near field) because of the low ambient water velocity. In AQUASEA, flow is modeled based on bathymetry, wind conditions, substrate roughness, external inflows and outflows, thermal stratification, and the Coriolis force. The transport and dispersion of pollutants is based on the modeled flows and discharge plume mixing processes. The software provides specific accommodations for modeling thermal discharge plumes.

The centerpiece of the AQUASEA model was a triangular element model of the Fox River and Green Bay in the vicinity of the PGS based on bathymetry. Other important input data were wind speed and direction, inflow from the Fox River, and cooling water intake and discharge from the PGS.

4.1   FINITE ELEMENT MODEL

The finite element model for the study area was constructed from 1100 nodes (points that are the vertices of the triangular elements) that produced 2000 elements. Nodes were located primarily on the shoreline of the river and on the 2-m interval depth contours (i.*e.*, 2, 4, 6, and 8 m). Additional nodes were placed between the depth contours to reduce the size of some elements and to add detail to the area of the discharge plume. Nodes were also placed at each cooling water outfall. Each element was assigned a depth equal to the average depth of the upper and lower depth contours that bounded the area in which the element was located (*e.g.*, 1, 3, 5 m, etc.) (Figure 4-1). The study area had to be extended beyond the range of the bathymetric map described above in an attempt to contain all of the modeled mixing zones. The bathymetric contours were extended out into the lake as far as possible based on an older bathymetric map[2] and USGS 7.5minute quadrangle maps.

Modes with known inflows and outflows were set as source/sink nodes (Figure 4-2). The upstream side of the study area was the inflow for the Fox River. Each node on this side was assigned a cross-sectional area based on the increment between the given node and next node to the south, and assigned a portion of the total river flow rate in proportion to the incremental cross-sectional area. These nodes were also assigned a flow direction of 24 degrees from north, which was equal to the centerline of the river as

---

[2]Burns & McDonnell Engineering Company, Inc. 2008. Section 316(b) 40 CFR 122.21(r) Information for the J.P. Pulliam Generating Station. Wisconsin Public Service. Green Bay, Wisconsin.
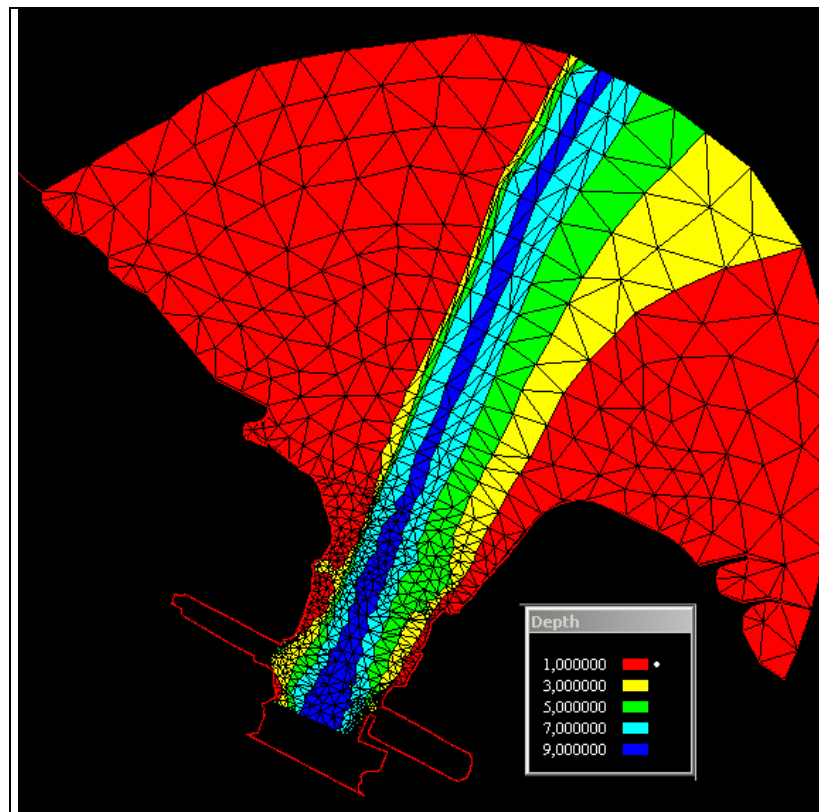
Figure 4-1:   Model elements for study area
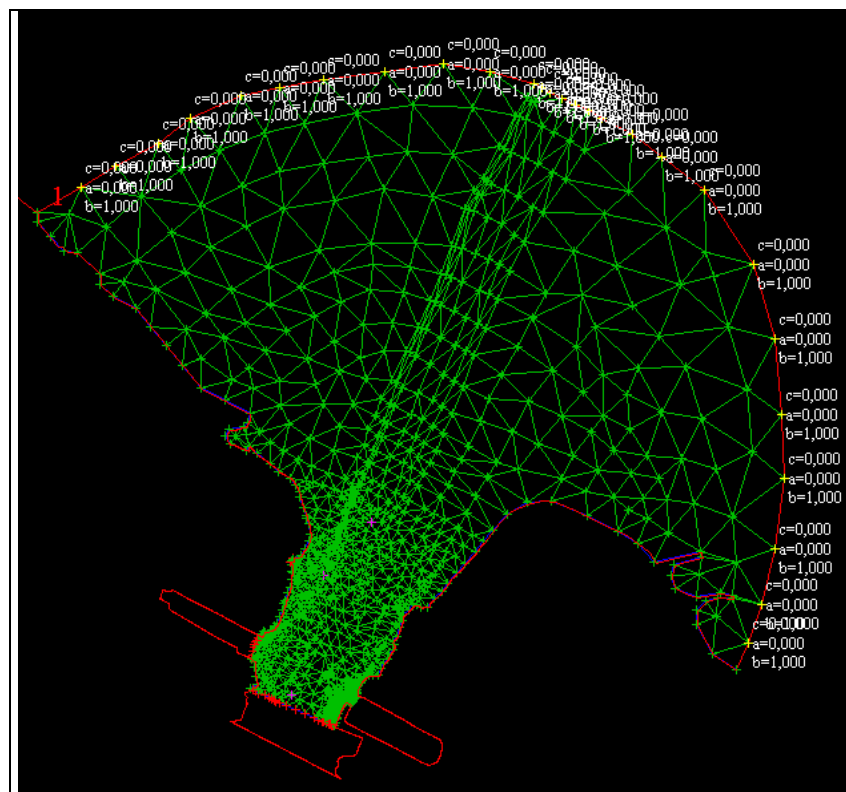
Figure 4-2:   Model nodes for study area

determined from aerial imagery. The temperature was set to zero degrees above ambient. The discharge nodes for the cooling system were assigned cross-sectional areas based on their width and depth and discharge rates prorated by their cross-sectional area. The discharge direction was set at 121 degrees from north based on the centerline of the lower portion of the discharge channel as determined from aerial imagery. The discharge temperature was the difference between the actual discharge temperature to be modeled and the ambient temperature. The nodes across the intake channel were set as sinks and assigned cross-sectional areas and negative flows in the same manner as the river inflow. The flow direction for the withdrawal was set at 301 degrees from north based on the centerline of the intake channel as determined from aerial imagery. The upstream end of the study area was specified as an open boundary for which the model calculated the speed, direction, and temperature of the flow out of the study area. Each node on this boundary was specified as a calculation boundary node. AQUASEA models open boundaries as being tidally influenced. In this case, the tidal amplitude at each calculation boundary node was set to zero to simulate a non-tidal situation. One node in each of the upstream, middle, and downstream portions of the study area was designated as a time series node to record flow speed, flow direction, and temperature at each time step in a model run.

4.2   SOURCE/SINK DATA

Two sets of source/sink data were developed. One set consisted of a time series for dynamic modeling of the week leading up to and concluding with the end of data collection for the plume mapping. River flow, however, could not be modeled dynamically because of the large data gap in several days leading up to the plume mapping. These data were used to calibrate the model. The second set consisted of static values representing monthly conditions for evaluating compliance with the temperature criteria. These data represented monthly average ambient conditions and maximum expected discharge conditions.

4.3   SURFACE WATER INFLOWS AND OUTFLOWS

Flow for the Fox River was represented by data from USGS gaging station 040851385. As previously indicated, calibration of the model was based on an initial flow assumption of 12,600 cfs. Monthly modeling used monthly 7-Q_{10}s (Table 4-1) calculated from daily flow data for 1989 through 2008 using the log-Pearson Type III methodology[3].

Table 4-1: Monthly 7-Q_{10}s for the Fox River at Green Bay, Wisconsin	
Month	**7-Q_{10} (cfs)**
January	2481
February	1911
March	2037
April	1848
May	1510
June	1445
July	1147
August	1126
September	869
October	1055
November	1632
December	2231

[3]U.S. Environmental Protection Agency. 1986. Technical Guidance Manual for Performing Wasteload Allocation, Book VI Design Conditions, Chapter 1 Stream Design Flow for Steady-State Modeling. 440/4-86-014. Office of Water Regulations and Standards. Washington, D.C.

Time varying discharge flow and temperature data for model calibration were obtained for the PGS records at one-hour intervals for July 14, 0:00 through July 21, 14:00, 2010. These data indicated that discharge temperature and flow were consistent over this period (Figure 4-3).

Figure 4-3:   Discharge flows and temperatures from the Pulliam Generating Station used for model calibration
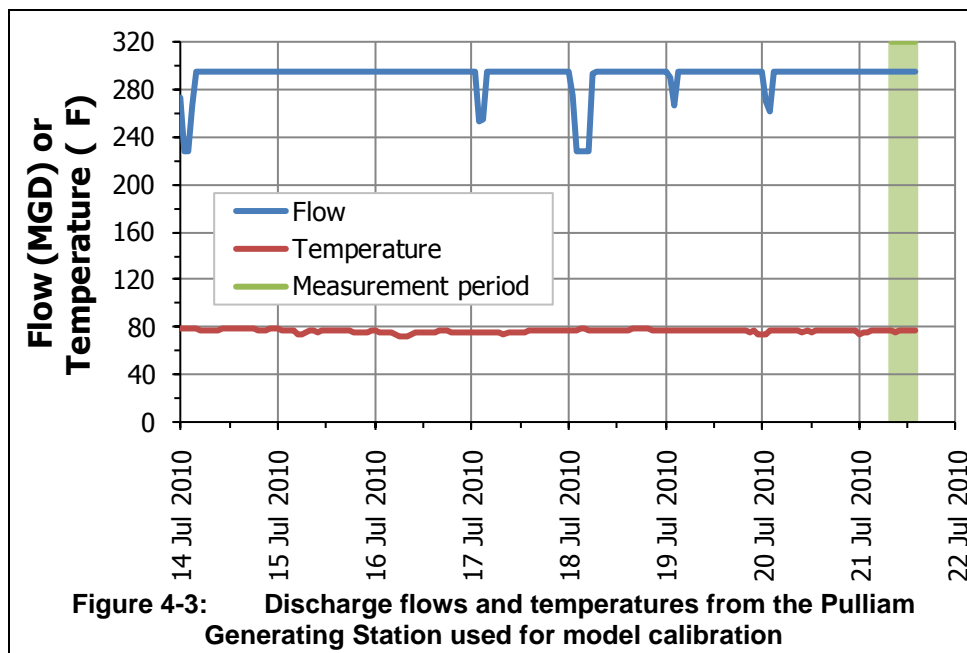
For evaluating compliance, daily maximum discharge temperatures were obtained from PGS records for January 1, 2008, through September 16, 2010. The period of record for these data was limited because prior data were not considered representative of current operating practices given the retirement of units 3 and 4 on December 31, 2007. Weekly averages (Sunday through Saturday) of the daily maximum temperatures were calculated (NR 106.52(10)). The maximum weekly average, 99[4] percentile weekly average[4], maximum daily temperatures, and 99th percentile daily maximum temperature were then extracted or calculated for each month (Table 4-2). The monthly discharge temperatures used to evaluate compliance were the greater of the maximum or the 99th percentile. In most months, the 99th percentile temperatures were greater than the maximum observed because of the relative small sample size that resulted from the limited duration of the appropriate period

Table 4-2: Discharge temperatures used to evaluate compliance				
	Weekly average		**Daily maximum**	
Month	**(°C)**	**(°F)**	**(°C)**	**(°F)**
January	16	60	18	64
February	14	56	17*	63*
March	20	68	21	70
April	25	76	25	78
May	33	91	37*	98*
June	34	94	36*	96*
July	37	98	37	99
August	39	101	39	103
September	35	95	36	96
October	32	90	34	93
November	25	77	26	78
December	16	61	19	65
*maximum, all other are 99th percentile				

---

[4] 99th percentile temperatures calculated using a Wisconsin Department of Natural Resources supplied worksheet.

of records. The combined design maximum circulating water rate for units 5 through 8, 422.8 MGD, was used to evaluate compliance for each month.

The discharge temperature data actually used in the model were adjusted to be relative to the background temperature. For calibration, the background temperature was set to 77.7 ºF (25.4 ºC), which was the observed ambient temperature when the discharge plume was mapped. The Wisconsin default water temperatures for southern Green Bay (Table 1-1) were used for monthly compliance evaluation modeling.

4.4   WIND DATA

As with the sources and sinks, a time series wind data set was developed for calibration and a set of monthly averages was developed for evaluating compliance. For the time-series, wind speed and direction data collected at 10- to 60-minute intervals were obtained for the Austin Straubel International Airport (weather station ID GRB / KGRB) from http://www.wunderground.com/ for July 7, 0:00 through July 21, 23:53, 2010 (Figure 4-4). Hourly wind speed and direction (degrees from north) data for the Austin Straubel International Airport from January 1, 2000, through December 31, 2009, were obtained from the National Climatic Data Center to provide a basis for calculating monthly averages (Table 4-3). Average wind directions were calculated using the true average vector method (http://www.ndbc.noaa.gov/ wndav.shtml).

Figure 4-4:   Wind speed and direction at the Austin Straubel International Airport, July 7 through July 22, 2010
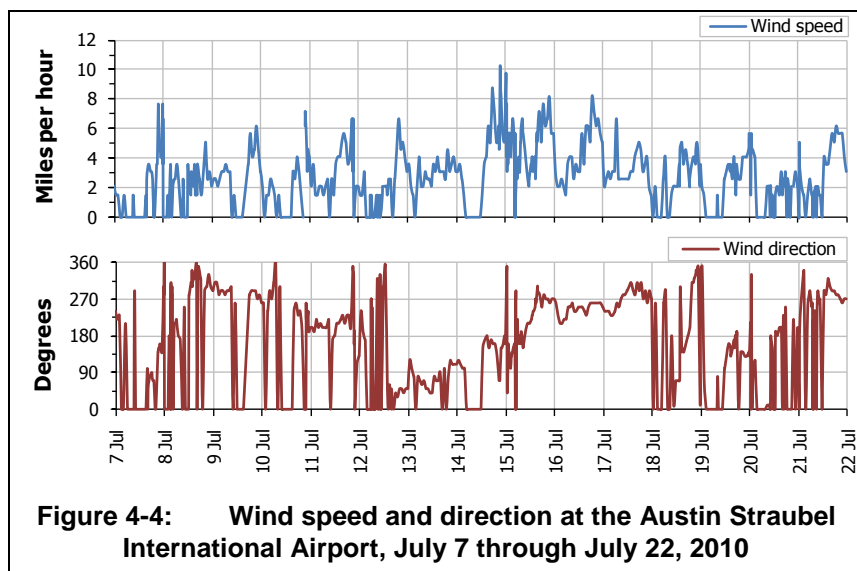
Table 4-3:   Monthly average wind speed and direction at the Austin Straubel International Airport, January 2001 – September 2009

Month	Speed (m/s)	Direction (degree)
January	1.9	289
February	1.9	318
March	1.9	347
April	2.3	38
May	1.9	80
June	1.5	236
July	1.4	264
August	1.3	254
September	1.4	241
October	1.7	256
November	2.0	287
December	1.9	273

4.5   MIXING DEPTH

The Fox River and the portion of Green Bay in the study area were assumed not to thermally stratify in the absence of the heated effluent from the PGS. For the flow portion of the model, the maximum mixing depth was set to the maximum-modeled depth of the study area, which was 9 m. For the transport portion

of the model, the mixing depth was set to 1.5 m to confine the plume to near the surface. This manipulation was necessary because AQUSEA is a two-dimensional model and does not consider the buoyant characteristics of thermal plumes. The choice of a mixing depth of 1.5 m was based on location of the great majority of the observed thermal plume within that region (Figure 3-3, Figure 3-4, and, Appendix A). AQUASEA's two-dimensional nature also means that the results of the transport model are average temperatures over the top 1.5 m. The output from the transport model, therefore, was compared to a thermal plume map based on the observed average temperatures from 0 through 1.5 m (Figure 4-5).

Figure 4-5:   Observed discharge plume temperatures averaged over the upper 1.5 m used for calibration

4.6   HEAT LOSS TO THE ATMOSPHERE

The transport portion of the model included an areal decay parameter (λ) to account for heat in the thermal plume lost to the atmosphere:

$$\lambda = \frac{K}{\rho C_p}$$

where K is the atmospheric heat loss coefficient (joules/m$^2\cdot$°C), p is the density of water (kilograms/m^3), and C_p is the specific heat of water (joules/kilogram$\cdot$°C). The atmospheric heat loss coefficient was calculated as:

$$K = 0.2388[4.6 - 0.09(T + c) + 4.06W]e^{0.033(T+c)}$$

where T is the air temperature (°C), c is the discharge temperature minus T (°C), and W is the wind speed (m/s) at an elevation of 2 m. The estimated λ for the calibration was $7.60\cdot10^7$. The λs corresponding to evaluating the monthly maximum 7-day average and maximum instantaneous maximum discharge temperatures are provided in Table 4-4. Details of the calculation of individual λs are provided in Appendix B.

4.7   CORIOLIS FORCE

The AQUASEA model can account for the affect of the Earth's rotation by entering the latitude of the site. The latitude entered for study site was 44.4 degrees north.

Table 4-4:   Areal decay constants for heat

Month	Maximum 7-Day Average	Maximum Instantaneous
January	$1.60\cdot10^{-06}$	$1.74\cdot10^{-06}$
February	$1.64\cdot10^{-06}$	$1.82\cdot10^{-06}$
March	$1.91\cdot10^{-06}$	$2.06\cdot10^{-06}$
April	$2.39\cdot10^{-06}$	$2.47\cdot10^{-06}$
May	$2.67\cdot10^{-06}$	$3.09\cdot10^{-06}$
June	$2.31\cdot10^{-06}$	$2.47\cdot10^{-06}$
July	$2.18\cdot10^{-06}$	$2.24\cdot10^{-06}$
August	$2.18\cdot10^{-06}$	$2.25\cdot10^{-06}$
September	$2.16\cdot10^{-06}$	$2.38\cdot10^{-06}$
October	$2.17\cdot10^{-06}$	$2.44\cdot10^{-06}$
November	$2.04\cdot10^{-06}$	$2.09\cdot10^{-06}$
December	$1.68\cdot10^{-06}$	$1.84\cdot10^{-06}$

5.0   MODEL CALIBRATION

The goal of calibrating the model was to obtain the best possible match between the predicted and observed plume temperatures. The process consisted of iterating input parameters and comparing the modeled plume temperature contours to the observed temperature contours.

The AQUASEA calibration runs simulated 48 hours beginning on July 17, 2010, at 14:30 and ending on July 21, 2010, at 14:30. The time-step was 15 seconds. Results at all nodes were recorded every 240 time-steps. The match of the modeled results to the observed plume temperature data was based on visual comparison of the modeled temperature isolines.

Initial calibration modeling at the USGS-estimated average daily river flow for July 21, 2010, 12,600 cfs, produced a plume that was much more defected in the downstream direction than the observed (Figure 5-1). Reductions in the river flow reduced the defection of the plume until a reasonable match to the overall plume trajectory was obtained at a river flow of 1,760 cfs. This substantial difference in the modeled and estimated flow is considered plausible because of the large documented daily variation in flow in this portion of the Fox River and the lack of actual flow measurements on July 21 (Figure 3-1). Adjustments to the transversal and longitudinal dispersion factors improved the match of the shape of the

Legend	
——	88 °F
——	86 °F
——	84 °F
——	82 °F
——	80 °F
——	78 °F

Figure 5-1:   Modeled discharge plume at river flow of 12,600 cfs.
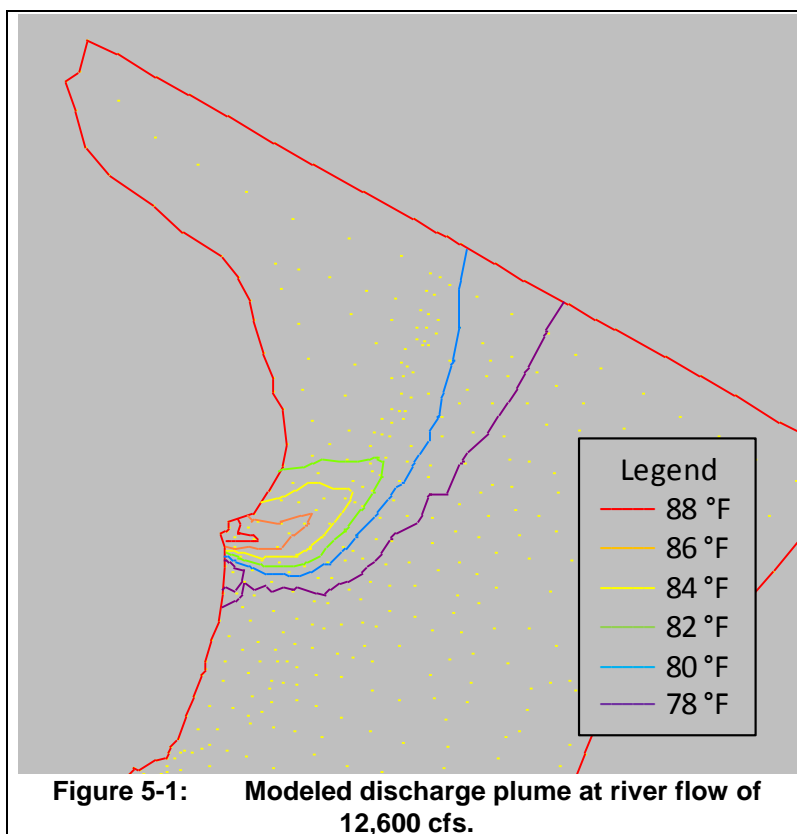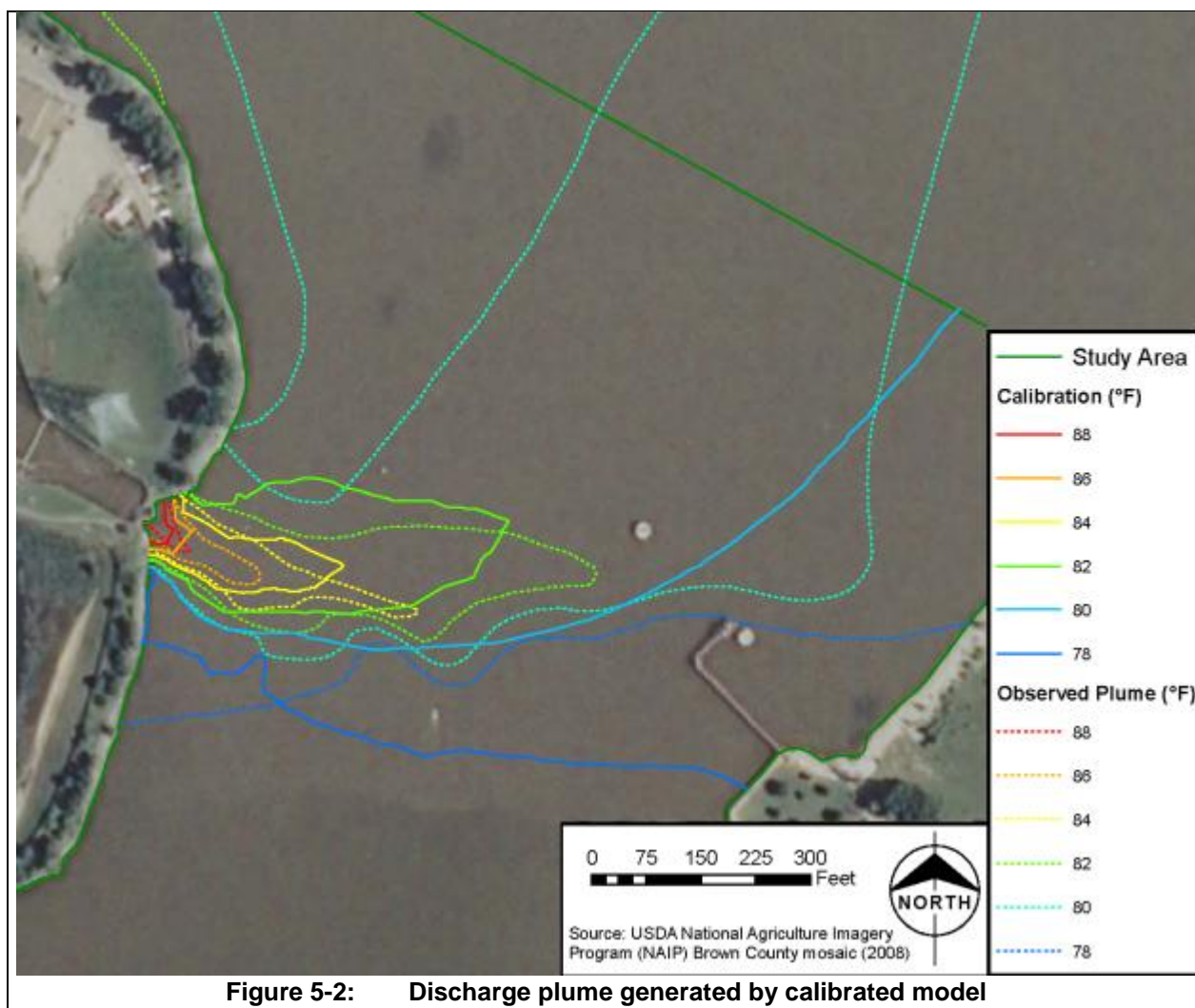
Figure 5-2:   Discharge plume generated by calibrated model

temperature isolines. Like the observed plume, the calibrated model plume had a 78-°F isoline that extended completely across the river, an 80-°F plume boundary that extended into the bay, and 82-, 84-,

86-, and 88-°F isolines that formed closed contours with the shoreline (Figure 5-2). The areas enclosed by the latter isolines were similar to the observed plume (Table 5-1).

The calibrated model incorporated the following parameter values in addition to the input data on bathymetry, flow, wind, and heat loss:

Table 5-1:	Temperature contour areas	
Temperature (°F)	Area (acres)	
	Observed*	Modeled
88	0.038	0.029
86	0.156	0.063
84	0.468	0.401
82	1.528	1.520

*based on average temperature for 0 to 1.5 m

- Wind shear stress: $1.5 \cdot 10^{-6}$ (default)
- Wind speed multiplier: 0 (default)

- Chezy (bottom friction) coefficient: 60 m$^{0.5}$/s (default)

- Chezy coefficient multiplier: 1.0 (default)

- Transversal diffusion multiplier: 0.6

- Longitudinal diffusion multiplier: 0.6

- Mixing depth multiplier (in transport model): 0.17

- Upstream weighting factor: 0 (default)

These parameters were carried over into the monthly modeling, except for wind speed multiplier. For calibration, wind speed was entered as a time-varying parameter, which disabled the wind speed multiplier. In the monthly runs, wind speed was a constant applied to all model elements, which enabled the wind speed multiplier. In this case, the wind speed multiplier was active and was set to 1.0 (no change).

As part of the calibration process, the adequacy of the 48-hour model run duration was evaluated by examining the stability of the modeled river flow speed, direction, and temperature. River flow and direction stabilized within 12 hours at all three time-series nodes (Figure 5-3). Temperature at the nodes fluctuated in response to changes in discharge temperature.

Figure 5-3:   Modeled river velocity, direction, and temperature at the time-series nodes under calibration conditions
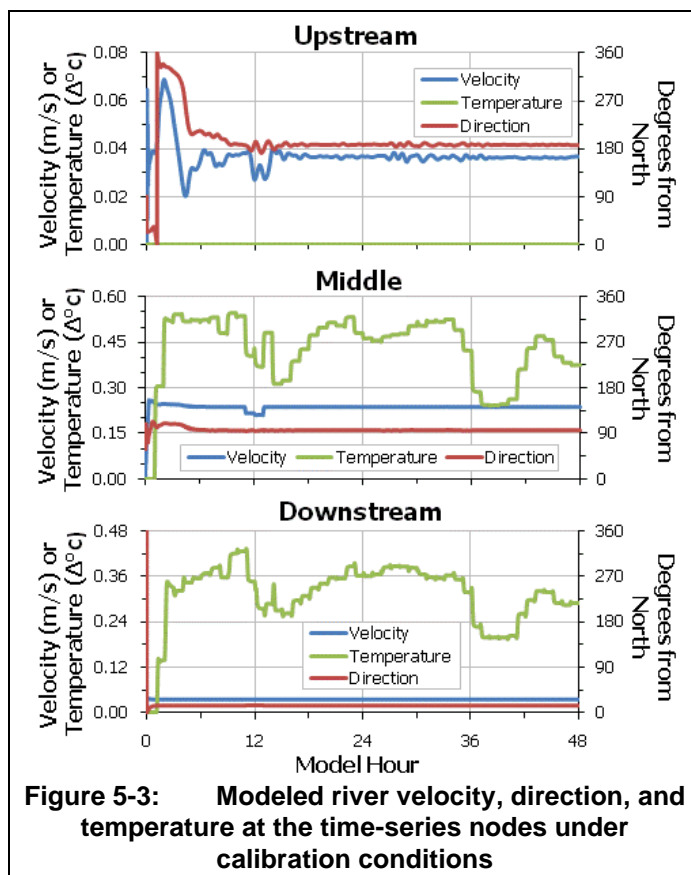
6.0   MIXING ZONE MODELING

Once the model was calibrated, the appropriate monthly data were substituted to estimate the size and shape of sub-lethal and acute mixing zones for each month. Acute mixing zones were not needed for December through April because the maximum daily discharge temperatures for those months were less than the respective acute temperature criteria as determined per NR 106.55 (Table 1-2). Temperature data were expressed as ºF above ambient and mixing zones were defined by the temperature contour lines equal to the difference between the default ambient temperatures and the corresponding temperature criteria.

The modeled sub-lethal mixing zones for January through June and July through December are presented in Figure 6-1 and Figure 6-2, respectively. The acute mixing zones are presented in Figure 6-3.

Figure 6-1:   Modeled sub-lethal mixing zones for January through June

Figure 6-2:   Modeled sub-lethal mixing zones for July through December
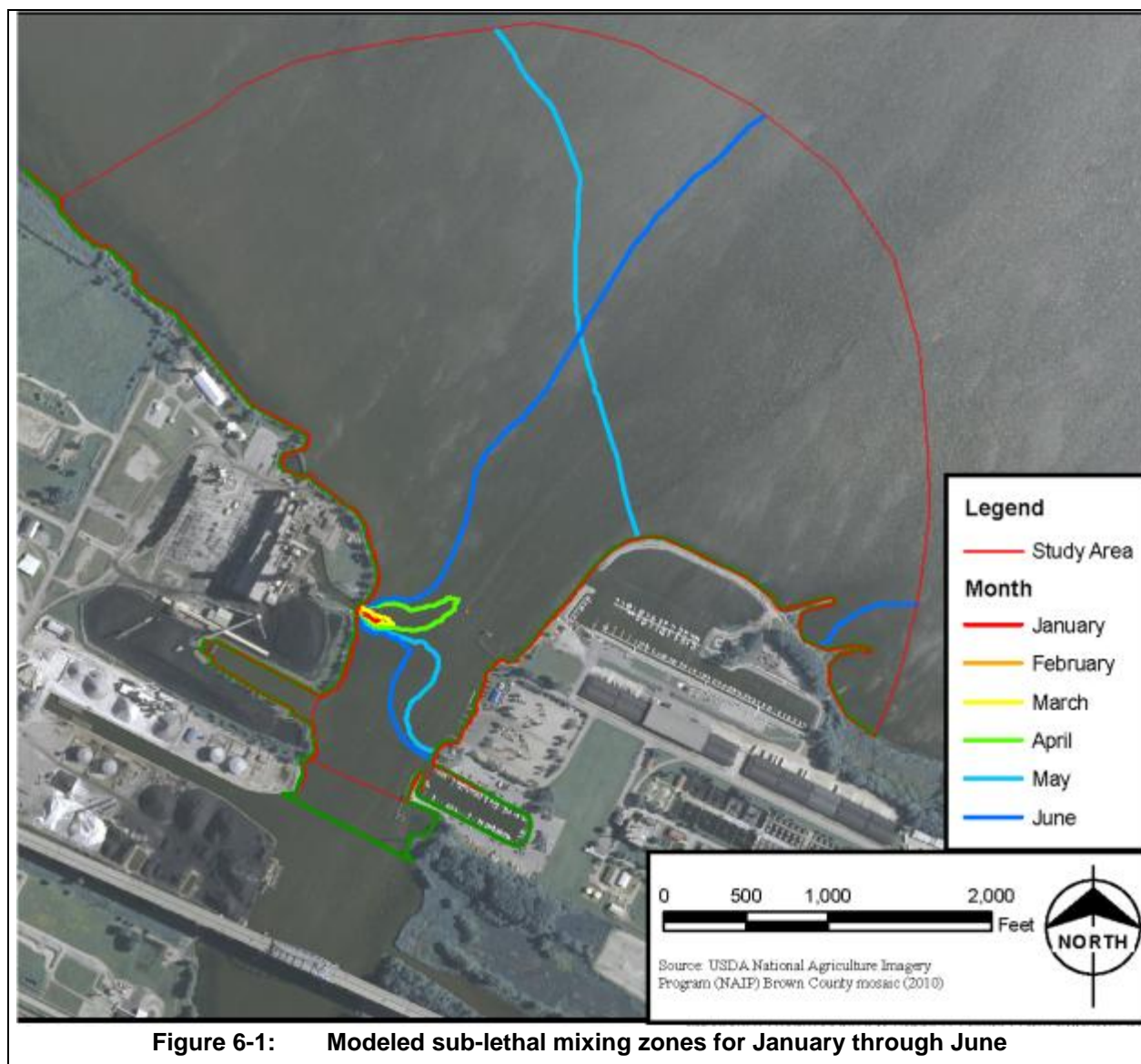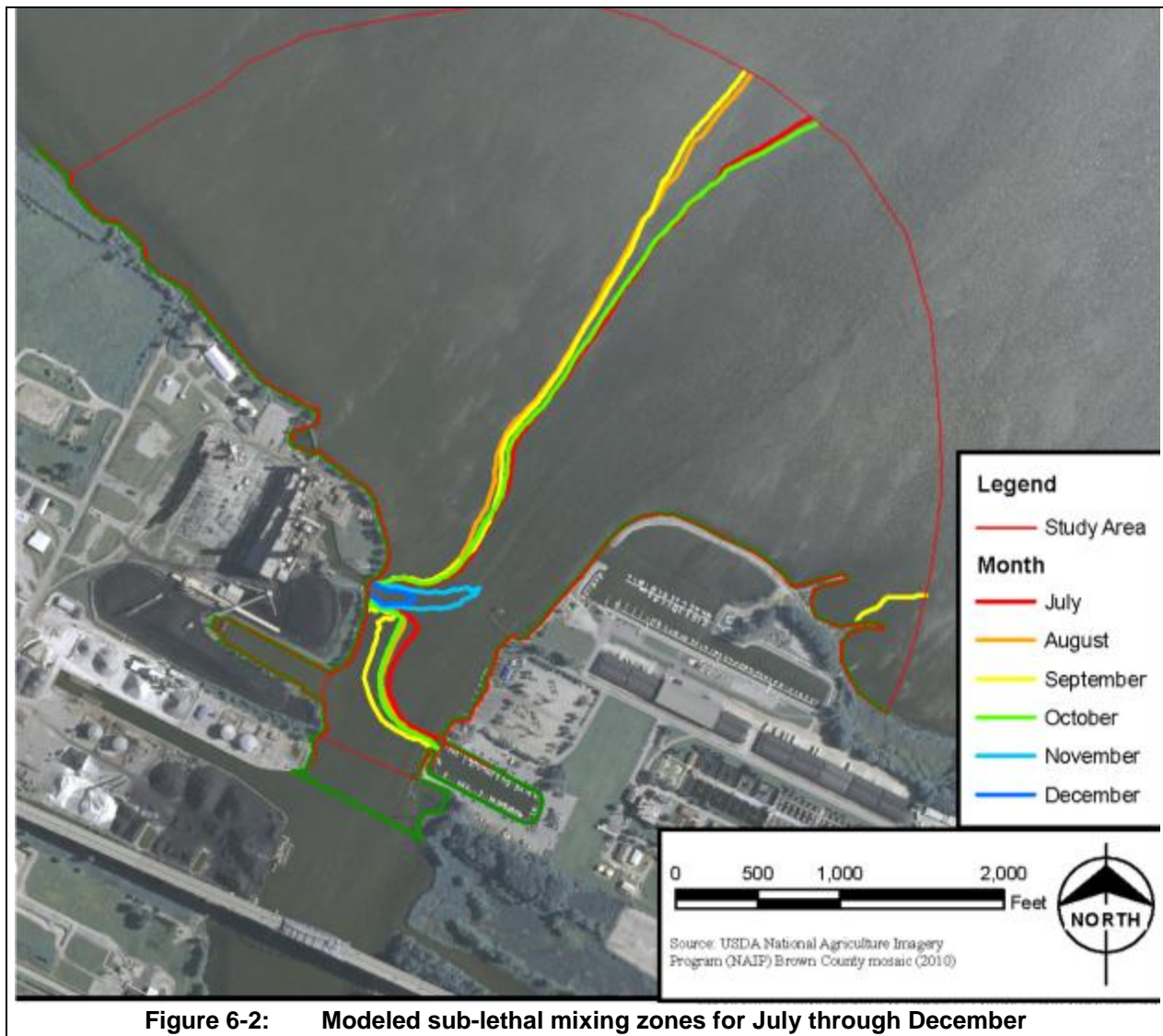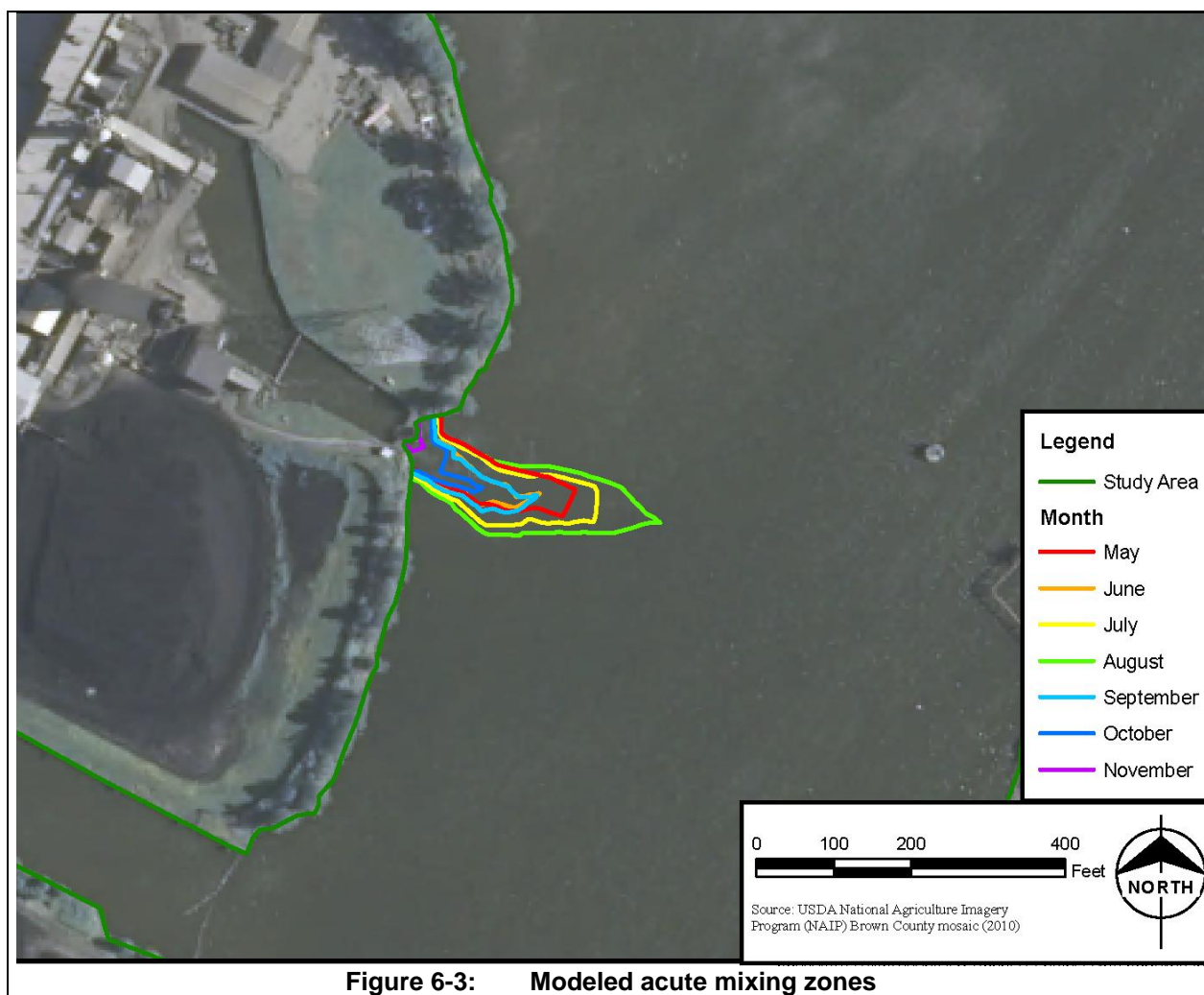
Figure 6-3:   Modeled acute mixing zones

The modeled sub-lethal mixing zones for November through April were contained completely within the study area and had surface areas ranging from 0.032 to 1.67 acres (Table 6-1). Because these areas are substantially less than 71.74 acres, the PGS does not have a reasonable potential to exceed the temperature criteria in these months. For May through October, the modeled sub-lethal mixing zones extended past the boundary of the study area, which prevented exact determinations of the areas of the mixing zones. The portions of the mixing zones that were within the study area, however, had areas that ranged from >141 to >183 acres.

The mixing zones in June through November extend completely across the Fox River. The extent to which these plumes also extend upstream appears to be a function of the modeled river

Table 6-1:   Modeled mixing zone areas for the thermal discharge plume from the Pulliam Generating Station

Month	Area (acres)	
	Sub-lethal	Acute
January	0.130	end of pipe
February	0.032	end of pipe
March	0.281	end of pipe
April	1.673	end of pipe
May	>182.861	0.272
June	>145.216	0.147
July	>140.988	0.377
August	>153.647	0.557
September	>150.114	0.166
October	>142.897	0.071
November	1.525	0.007
December	0.493	end of pipe

flow. For example, September had the lowest 7-Q_{10} (Table 4-1) and the greatest upstream intrusion. Wind also played a role in the shape if the mixing zones. For June through October, the modeled wind directions were approximately west south-west. This wind direction likely contributed to pushing the thermal plume out into Green Bay and east of the mouth of the river. In May, the model wind direction was from the east, which pushed the plume to the west side of the Green Bay portion of the study area. The wind direction and plume location were the reverse of May in July through October.

The modeled acute mixing zones ranged in area from 0.032 to 1.673 acres and were much less than 71.64 acres for all months (Table 6-1); therefore, the PGS does not have a reasonable potential to exceed the acute temperature criteria.

7.0   REQUESTED LIMITS

With estimated mixing zone areas of less than two acres, the facility does not have a reasonable potential to exceed the acute temperature criteria at the edge of the mixing zone and therefore, acute temperature limitations in the WPDES permit are not necessary. Mixing zone areas corresponding to the sub-lethal criteria were no greater than 1.70 acres for the months of November through April. Therefore, no potential exists to exceed the sub-lethal criteria in these months and sub-lethal temperature limitations are not necessary. The modeling results indicate the facility has a reasonable potential to exceed the mixing zone limitations found in NR 106 during the months of May through October. As a result, sub-lethal temperature limits are necessary during these months. The alternate effluent limitations for temperature being requested in Table 7-1 are the P99 value calculated for the given month as allowed in NR 106.56(3)(b) and NR 106.55(13). The P99 value

Table 7-1: Requested temperature limits for the cooling water discharge from the Pulliam Generating Station		
Month	Sub-lethal	Acute
January	none	none
February	none	none
March	none	none
April	none	none
May	91	none
June	94	none
July	98	none
August	101	none
September	95	none
October	90	none
November	none	none
December	none	none

was calculated using representative weekly average effluent temperatures recorded at the facility during calendar years 2008 through 2010.

The estimated 99th percentile weekly average maximums are requested as sub-lethal limits for May through October (Table 7-1) based on compliance with NR 106.55(10), Limitations Based on Site-Specific Mixing Zone Analysis.

7.1   NR 106.55(10)(a)

The first requirement for a request for limitations based on a site-specific mixing zone analysis is a "mixing zone analysis that details the full extent of and condition of the mixing zone" (§§(10)(a)). The thermal plume mapping and modeling conducted for PGS and reported above describes the three dimensional extent of the thermal plume and variations in the plume under the predominant conditions for each month.

7.2   NR 106.55(10)(b)

The proposed limitations must also demonstrate that the mixing zone provisions at NR 102.05(3) are met. §§(3)(a) indicates that mixing zones should be as small as practicable and conform to the time exposure response to aquatic life. The requested sub-lethal limits for May through October are the estimated 99th percentile seven-day average discharge temperatures based on discharge temperature data collected after

the retirement of Units 3 and 4 in December 2007. The resulting mixing zones, therefore, are as small as possible without resorting to plant de-rating, extensive modifications to the discharge structures, or changing the cooling system from open-cycle to closed-cycle. Such changes in operations and configuration are considered impractical because of the significant expenses that would be entailed, which are estimated in the tens of millions of dollars for capital expenditure and/or lost generation capacity.[5] A simple modification to the discharge structure intended to increase discharge velocity and increase near field mixing, closing one of the outfall openings, was modeled by modifying the above model inputs, and found instead to increase the mixing zone area. This result suggests that improved mixing could only be achieved by installing a submerged multiport diffuser. Such a modification would be extensive and expensive and could be disallowed by the U.S. Army Corps of Engineers and the U.S. Coast Guard because of potential interference with navigation.

Mixing zones must provide passageways for fish and other mobile organisms (§§(3)(b)). The mixing zones at the PGS originate at the shoreline of the Fox River and extend out into Green Bay. Plume mapping demonstrated that the vertical extent of the plume leaves ample room for mobile aquatic organisms to avoid areas of sub-lethal temperatures because the thermal plume floats on the surface of the river and bay, which allows a substantial passageway under the mixing zone.

§§(3)(c) limits the width and cross-sectional area of mixing zones in a unidirectionally flowing water body to 50 and 25 percent, respectively. At the low flow conditions modeled, the mixing zones did not comply with the width requirement in §§(3)(c), but might have complied with the cross-sectional area requirement given the buoyant nature of the thermal plume. At higher flows, modeling indicated that the mixing zones would be deflected, would not completely cross the river, and could comply with the width limitation. Because §§(3)(c) applies to unidirectionally flowing water bodies, then these restrictions are not strictly applicable to the PGS's discharge into this portion of the Fox River, which exhibits flow reversals.

Acute toxicity criteria and secondary acute values developed pursuant to NR 105.05 shall not be exceeded at any point in the mixing zone (§§(3)(d)). Based on the plume modeling, the thermal discharge from the PGS will always meet the acute temperature criteria within the default mixing zone size limit (Table 6-1).

---

[5]Burns & McDonnell. 2005, Section 316(b) Compliance Feasibility Study for the J.P. Pulliam Generating Station. Wisconsin Public Service. Green Bay, Wisconsin.

§§(3)(e) limits the surface area of mixing zones in inland lakes. This restriction is not applicable to the PGS discharge into Green Bay, which is not considered an inland lake in NR 102 Subchapter II or NR 106 Subchapter V.

Mixing zones shall not adversely impact spawning or nursery areas, migratory routes, or the mouths of tributary streams (§§(3)(f)). The aquatic habitat in the vicinity of the PGS discharge plume is unremarkable except for anthropogenic impacts unrelated to the thermal discharge from the PGS. The lower Fox River has substantial commercial shipping. The shoreline has been largely modified with sheet pilings, rip-rap, and side channels for unloading, and the main channel is routinely dredged. The dredged shipping channel extends into Green Bay. In addition, the substrate in the vicinity of the mouth of the Fox River is contaminated with polychlorinated biphenyls. Some spawning and nursery areas for fish may be present in Green Bay in the shallow waters to the west and east of the mouth of the Fox River. Modeling indicated that these areas would sometimes be included within the sub-lethal mixing zone generated by the PGS in May through October. The PGS has been operating for over 70 years and at times with six units. No appreciable harm to fish or other aquatic life has been documented as attributable to the facility's thermal discharge. The mixing zones currently generated by the PGS, therefore, are not expected to adversely affect spawning or nursery areas or migratory routes. Aside from the mixing zone occasionally extending across the mouth of the Fox River at the surface, no other mouths of tributaries to Green Bay or the Fox River are present in the expected mixing zones.

§§(3)(g) states that mixing zones should not overlap. The Green Bay Metropolitan Wastewater Treatment Facility discharges to the Fox River across the river from the PGS.[6] Plume modeling indicated that the thermal mixing zone from the PGS sometimes extends across the river and contacts a portion of shoreline that includes the wastewater plant outfall. The thermal mixing zone from the PGS, therefore, can overlap the mixing zone from the wastewater plant under certain conditions. The concentrations of numerous pollutants are monitored in the effluent from the wastewater treatment plant including biological oxygen demand, pH, total suspended solids, ammonia, total phosphorus, fecal coliform bacteria, total residual chlorine, and several heavy metals. Temperature, however, is not monitored, which indicates that the wastewater treatment plant does not have a mixing zone for temperature. As such, the thermal mixing zone from the PGS will not overlap another thermal mixing zone. The heat from the PGS discharge could increase the rate at which biological oxygen demand components in the wastewater treatment plant effluent are assimilated.

---

[6]http://www.epa-echo.gov/cgi-bin/get1cReport.cgi?tool=echo&IDNumber=WI0020991

The pH of the discharge from the PGS is expected to be similar to the pH of water in the Fox River and to comply with the pH water quality criteria at the point of discharge. As such, the thermal mixing zone at the PGS will comply with §§(3)(h).

7.3   NR 106.55(10)(c)

The PGS is located in Segment 3 (river mile 0 to 7.3) of the Lower Fox River. This river segment has been on the Wisconsin Section 303(d) list of impaired waters since 1998. One of the designated uses for this water body is warm water sport fishery. This use is impaired because of low dissolved oxygen and a fish consumption advisory. The causal pollutants are phosphorus and polychlorinated biphenyls.[7] The PGS has been operating for over 70 years, including times when output was higher than current capacity. Temperature has not been implicated as a cause of the lower Fox River's impairment. The lack of appreciable harm associated with historical thermal discharges from the PGS suggests that the current thermal discharge would allow the attainment of all designated uses in the lower Fox River in the absence of the listed causes of impairment.

7.4   NR 106.55(10)(d)

The purpose of water quality standards and criteria are to protect the designated uses of water bodies receiving potentially polluted effluents. The designated uses for the Fox River are fish and aquatic life (warm water sport fishery), recreation, public health and welfare, and wildlife.[8] The designated uses for Green Bay are public water supply, recreation, commercial and recreational fishing, industrial and cooling water, and waste assimilation (NR 104 .24(4)). No evidence exists to indicate that the cooling water discharge from the PGS has adversely impacted any of the designated uses of the Fox River or Green Bay. Because the requested discharge limits for May through October are based on historical discharge temperatures and past discharges have not adversely impacted the Fox River's or Green Bay's designated uses, the request limits will provide a level of protection equivalent to that provided by discharge temperature limits based on the default mixing zone size.

7.5   SUMMARY

Based on a site-specific mixing zone analysis, historical operation, and a lack of appreciable harm, the proposed thermal discharge limits (Table 7-1) for the PGS are found to comply with the requirements at NR 106.55(10) for the calculation of effluent limits that differ from those determined by water-quality based effluent limitation method at NR 106.55(7). The proposed limits found in Table 7-1, therefore, are

---

[7]Wisconsin Department of Natural resources Proposed Impaired Waters List – September 27, 2006.
[8]http://dnr.wi.gov/org/water/wm/wqs/usedesignations.htm

requested for inclusion in the next Wisconsin Pollutant Discharge Elimination System Permit for the PGS.

APPENDIX A - TEMPERATURE MEASUREMENTS OF THE THERMAL PLUME

Thermal Plume Measurements

Sample Date: 21-Jul-10

Thermistor temperature (°C): 23.7
Calibration thermometer temperature (°C): 25.6
Temperature correction (°C): 1.9

ORIGINAL DATA

Transect: A

Depth (m)	1	2	3	4	5	6	7	8	9
0.0	23.7	23.6	23.6	23.5	23.5				
0.5		23.6	23.5	23.5	23.5				
1.0			23.5	23.5	23.5				
1.5			23.5	23.5	23.5				
2.0				23.5	23.5				
2.5				23.5	23.5				
3.0				23.5	23.5				
3.5				23.5	23.5				
4.0				23.5	23.5				
4.5				23.5	23.5				
5.0				23.5	23.5				
5.5				23.5	23.4				

Transect: B

Depth (m)	1	2	3	4	5	6	7	8	9
0.0	23.9	23.6	23.6	26.2	23.6	23.6			
0.5	23.8	23.6	23.6	24.8	23.6	23.6			
1.0		23.6	23.6	23.6	23.6	23.6			
1.5			23.5		23.5	23.5			
2.0					23.5	23.5			
2.5					23.5	23.5			
3.0					23.6	23.5			
3.5					23.6	23.5			
4.0					23.5	23.5			
4.5					23.5	23.5			
5.0					23.5	23.5			
5.5					23.5	23.5			

Transect: C

Depth (m)	1	2	3	4	5	6	7	8	9
0.0	23.8	25.8	26.3	27.9	27.4	23.6			
0.5		25.1	26.3	26.7	27.6	23.7			
1.0		23.9	23.9	26.8	24.2	23.7			
1.5					23.6	23.6			
2.0					23.5	23.6			
2.5					23.5	23.6			
3.0					23.5	23.6			
3.5					23.5	23.6			
4.0					23.5	23.6			
4.5					23.5	23.5			
5.0					23.5	23.5			
5.5					23.5	23.5			

Transect: D

Depth (m)	1	2	3	4	5	6	7	8	9
0.0	30.0	29.6	28.9	28.6	27.4	23.7			
0.5	30.0	29.5	28.9	28.2	27.5	23.7			
1.0	29.8	29.4	28.7	28.1	26.9	23.6			
1.5	29.8	29.3	28.6	26.5	26.7	23.6			
2.0	28.9	28.3	27.8		25.6	23.6			
2.5	28.9	27.8	26.2		23.9	23.5			
3.0	27.9	27.6			23.6	23.5			
3.5		26.2			23.5	23.5			
4.0					23.5	23.5			
4.5					23.5	23.5			
5.0					23.5	23.5			
5.5					23.5	23.5			

Transect: E

Depth (m)	1	2	3	4	5	6	7	8	9
0.0	25.1	27.1	27.2	26.7	25.8	27.1	27.0	26.4	23.7
0.5	24.7	27.6	26.4	26.4	25.8	27.0	26.5	26.0	23.7
1.0		27.3	25.6	25.3	25.5	25.1	25.6	25.9	23.7
1.5		26.5	23.8	23.8	24.4	24.8	24.7	25.6	23.6
2.0		25.3			24.0	23.6	24.5	24.9	23.5
2.5		24.5			23.8	23.6	24.4	24.9	23.5
3.0		24.2				23.6	24.7	24.0	23.4
3.5						23.5	24.0	24.2	23.3
4.0						23.5	23.5	24.2	23.3
4.5						23.5	23.5	23.8	23.2
5.0						23.5	23.5	23.6	
5.5						23.5	23.5	23.6	

CORRECTED DATA

Transect: A

Depth (m)	1	2	3	4	5	6	7	8	9
0.0	25.6	25.5	25.5	25.4	25.4				
0.5		25.5	25.4	25.4	25.4				
1.0			25.4	25.4	25.4				
1.5			25.4	25.4	25.4				
2.0				25.4	25.4				
2.5				25.4	25.4				
3.0				25.4	25.4				
3.5				25.4	25.4				
4.0				25.4	25.4				
4.5				25.4	25.4				
5.0				25.4	25.4				
5.5				25.4	25.3				

Transect: B

Depth (m)	1	2	3	4	5	6	7	8	9
0.0	25.8	25.5	25.5	28.1	25.5	25.5			
0.5	25.7	25.5	25.5	26.7	25.5	25.5			
1.0		25.5	25.5	25.5	25.5	25.5			
1.5			25.4		25.4	25.4			
2.0					25.4	25.4			
2.5					25.4	25.4			
3.0					25.5	25.4			
3.5					25.5	25.4			
4.0					25.4	25.4			
4.5					25.4	25.4			
5.0					25.4	25.4			
5.5					25.4	25.4			

Transect: C

Depth (m)	1	2	3	4	5	6	7	8	9
0.0	25.7	27.7	28.2	29.8	29.3	25.5			
0.5		27.0	28.2	28.6	29.5	25.6			
1.0		25.8	25.8	28.7	26.1	25.6			
1.5					25.5	25.5			
2.0					25.4	25.5			
2.5					25.4	25.5			
3.0					25.4	25.5			
3.5					25.4	25.5			
4.0					25.4	25.5			
4.5					25.4	25.4			
5.0					25.4	25.4			
5.5					25.4	25.4			

Transect: D

Depth (m)	1	2	3	4	5	6	7	8	9
0.0	31.9	31.5	30.8	30.5	29.3	25.6			
0.5	31.9	31.4	30.8	30.1	29.4	25.6			
1.0	31.7	31.3	30.6	30.0	28.8	25.5			
1.5	31.7	31.2	30.5	28.4	28.6	25.5			
2.0	30.8	30.2	29.7		27.5	25.5			
2.5	30.8	29.7	28.1		25.8	25.4			
3.0	29.8	29.5			25.5	25.4			
3.5		28.1			25.4	25.4			
4.0					25.4	25.4			
4.5					25.4	25.4			
5.0					25.4	25.4			
5.5					25.4	25.4			

Transect: E

Depth (m)	1	2	3	4	5	6	7	8	9
0.0	27.0	29.0	29.1	28.6	27.7	29.0	28.9	28.3	25.6
0.5	26.6	29.5	28.3	28.3	27.7	28.9	28.4	27.9	25.6
1.0		29.2	27.5	27.2	27.4	27.0	27.5	27.8	25.6
1.5		28.4	25.7	25.7	26.3	26.7	26.6	27.5	25.5
2.0		27.2			25.9	25.5	26.4	26.8	25.4
2.5		26.4			25.7	25.5	26.3	26.8	25.4
3.0		26.1				25.5	26.6	25.9	25.3
3.5						25.4	25.9	26.1	25.2
4.0						25.4	25.4	26.1	25.2
4.5						25.4	25.4	25.7	25.1
5.0						25.4	25.4	25.5	
5.5						25.4	25.4	25.5	

Transect: F

Depth (m)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
0.0	24.7	25.1	23.8	25.5	25.6	25.4	26.2	25.4	23.8	26.6	27.0	25.7	27.4	27.5	27.3	28.1	27.3	25.7
0.5	24.7	24.0	23.8	25.5	25.0	25.3	26.1	25.3	23.9	26.6	25.9	25.7	27.4	26.9	27.2	28.0	27.2	25.8
1.0			23.6	24.5	25.0	25.2	25.3	23.9	23.9			25.5	26.4	26.9	27.1	27.2	25.8	25.8
1.5				24.2	24.5	24.9	24.9	23.8					26.1	26.4	26.8	26.8	25.7	
2.0				23.8	24.5	24.8	24.4	23.8					25.7	26.4	26.7	26.3	25.7	
2.5				24.1	23.9	24.6	23.8	23.8					26.0	25.8	26.5	25.7	25.7	
3.0				23.8	23.8	24.5	23.6	23.7					25.7	25.7	26.4	25.5	25.6	
3.5				23.6	23.6	24.2	23.5						25.5	25.5	26.1	25.4		
4.0				23.5	23.5	23.8	23.5						25.4	25.4	25.7	25.4		
4.5				23.5	23.5	23.6	23.5						25.4	25.4	25.5	25.4		
5.0				23.5	23.5	23.6							25.4	25.4	25.5			
5.5				23.5	23.5	23.5							25.4	25.4	25.4			

Transect: G

Depth (m)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
0.0	25.8	24.6	24.9	25.6	26.0	25.8	23.8			27.7	26.5	26.8	27.5	27.9	27.7	25.7
0.5		24.3	24.8	25.7	25.9	24.6	23.8				26.2	26.7	27.6	27.8	26.5	25.7
1.0			24.5	25.2	25.9	25.9	23.8					26.4	27.1	27.8	26.4	25.7
1.5			24.3	24.7	24.3	24.0	23.8					26.2	26.6	26.2	25.9	25.7
2.0			23.8	24.2	24.5	23.8						25.7	26.1	26.4	25.7	
2.5			23.9	24.0	24.0	23.6						25.8	25.9	25.9	25.5	
3.0			23.6	23.7	23.9	23.5						25.5	25.6	25.8	25.4	
3.5			23.6	23.6	23.8							25.5	25.5	25.7		
4.0			23.6	23.6	23.6							25.5	25.5	25.5		
4.5			23.5	23.5	23.6							25.4	25.4	25.5		
5.0			23.5	23.5	23.6							25.4	25.4	25.5		
5.5			23.5	23.5								25.4	25.4			

Transect: H

Depth (m)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
0.0	25.9	24.5	24.7	25.6	25.8	25.3	23.8			27.8	26.4	26.6	27.5	27.7	27.2	25.7
0.5		24.4	24.6	25.5	25.5	24.9	23.8				26.3	26.5	27.4	27.4	26.8	25.7
1.0		24.3	24.2	25.3	25.0	24.3	23.7				26.2	26.1	27.2	26.9	26.2	25.6
1.5			23.8	24.8	24.4	24.0	23.6					25.7	26.7	26.3	25.9	25.5
2.0			23.6	24.5	24.3	23.8						25.5	26.4	26.2	25.7	
2.5				24.2	23.6	23.7							26.1	25.5	25.6	
3.0				23.7	23.6	23.6							25.6	25.5	25.5	
3.5				23.6	23.6								25.5	25.5		
4.0				23.5	23.6								25.4	25.5		
4.5				23.5									25.4			
5.0				23.5									25.4			
5.5				23.5									25.4			

Transect: I

Depth (m)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
0.0	26.2	24.7	24.5	25.3	25.8	23.8	25.5			28.1	26.6	26.4	27.2	27.7	25.7	27.4
0.5		24.7	24.4	24.9	25.0	23.7	24.7				26.6	26.3	26.8	26.9	25.6	26.6
1.0			24.4	24.2	24.7	23.7	23.8					26.3	26.1	26.6	25.6	25.7
1.5				24.1	24.6	23.6	23.7						26.0	26.5	25.5	25.6
2.0				23.8	24.2	23.6	23.6						25.7	26.1	25.5	25.5
2.5				23.7	24.1	23.6	23.6						25.6	26.0	25.5	25.5
3.0				23.6	23.9		23.6						25.5	25.8		25.5
3.5				23.6	23.8								25.5	25.7		
4.0				23.6	23.5								25.5	25.4		
4.5				23.5									25.4			
5.0				23.5									25.4			
5.5				23.5									25.4			

Transect: J

Depth (m)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
0.0	25.5	25.1	24.5	25.0	25.5	23.9	24.0			27.4	27.0	26.4	26.9	27.4	25.8	25.9
0.5	25.5	25.1	24.5	24.9	25.3	23.9	24.0			27.4	27.0	26.4	26.8	27.2	25.8	25.9
1.0	25.3	24.9	24.4	23.8	24.4	23.9	24.0			27.2	26.8	26.3	25.7	26.3	25.8	25.9
1.5			24.2	23.7	24.3	23.8	24.0					26.1	25.6	26.2	25.9	25.9
2.0				23.7	24.2	23.8	24.0						25.6	26.1	25.7	25.9
2.5				23.7	23.9	23.8							25.6	25.8	25.7	
3.0				23.6	23.8								25.5	25.7		
3.5					23.8									25.7		
4.0																
4.5																
5.0																
5.5																

APPENDIX B - HEAT LOSS PARAMETER CALCULATIONS

Heat Loss Parameter Calculation

	Reference T[1]		Wind Speed		Discharge T		Excess T	K	Density	Sp. Heat	λ
	°F	°C	mph	m/s	°F	°C	°C	$J/m^2 \cdot °C$	kg/m^3	$J/kg \cdot °C$	m/s
Calibration	80.4	26.9	1.6	0.7	89.2	31.8	4.9	3.2	995.128	4186	7.60E-07
Maximum 7-Day Average Discharge Temperatures											
January	15.6	-9.1	7.8	3.5	57.6	14.2	23.3	6.7	999.209	4186	1.60E-06
February	20.5	-6.4	8.3	3.7	56.3	13.5	19.9	6.9	999.305	4186	1.64E-06
March	31.3	-0.4	8.5	3.8	64.9	18.3	18.6	8.0	998.555	4186	1.91E-06
April	44.2	6.8	9.5	4.2	72.9	22.7	15.9	10.0	997.629	4186	2.39E-06
May	56.4	13.6	8.1	3.6	88.6	31.4	17.9	11.1	995.238	4186	2.67E-06
June	65.4	18.6	6.6	2.9	91.4	33.0	14.5	9.6	994.729	4186	2.31E-06
July	69.9	21.1	5.9	2.6	94.0	34.4	13.4	9.1	994.252	4186	2.18E-06
August	67.5	19.7	5.7	2.6	95.6	35.3	15.6	9.1	993.952	4186	2.18E-06
September	58.8	14.9	6.3	2.8	89.8	32.1	17.2	9.1	995.016	4186	2.18E-06
October	47.4	8.6	7.1	3.2	82.3	27.9	19.4	9.0	996.281	4186	2.17E-06
November	34.0	1.1	7.7	3.4	74.3	23.5	22.4	8.5	997.442	4186	2.04E-06
December	21.2	-6.0	8.1	3.6	59.1	15.1	21.1	7.0	999.084	4186	1.68E-06
Maximum Instantaneous Discharge Temperature											
January	15.6	-9.1	7.8	3.5	63.0	17.2	26.3	7.3	998.739	4186	1.74E-06
February	20.5	-6.4	8.3	3.7	63.0	17.2	23.6	7.6	998.739	4186	1.82E-06
March	31.3	-0.4	8.5	3.8	69.7	21.0	21.4	8.6	998.015	4186	2.06E-06
April	44.2	6.8	9.5	4.2	75.0	23.9	17.1	10.3	997.346	4186	2.47E-06
May	56.4	13.6	8.1	3.6	98.0	36.7	23.1	12.9	993.475	4186	3.09E-06
June	65.4	18.6	6.6	2.9	96.0	35.6	17.0	10.3	993.869	4186	2.47E-06
July	69.9	21.1	5.9	2.6	96.0	35.6	14.5	9.3	993.869	4186	2.24E-06
August	67.5	19.7	5.7	2.6	98.0	36.7	16.9	9.4	993.475	4186	2.25E-06
September	58.8	14.9	6.3	2.8	96.0	35.6	20.7	9.9	993.869	4186	2.38E-06
October	47.4	8.6	7.1	3.2	90.0	32.2	23.7	10.1	994.986	4186	2.44E-06
November	34.0	1.1	7.7	3.4	76.0	24.4	23.3	8.7	997.209	4186	2.09E-06
December	21.2	-6.0	8.1	3.6	65.0	18.3	24.3	7.7	998.540	4186	1.84E-06

[1]Air temperature for calibration was based on data from the Green Bay Airport from 08:53 to 14:00 on July 21, 2010 and obtained via www.wunderground.com. Historical monthly average temperatures where obtained from http://lwf.ncdc.noaa.gov/oa/climate/online/ccd/meantemp.html.